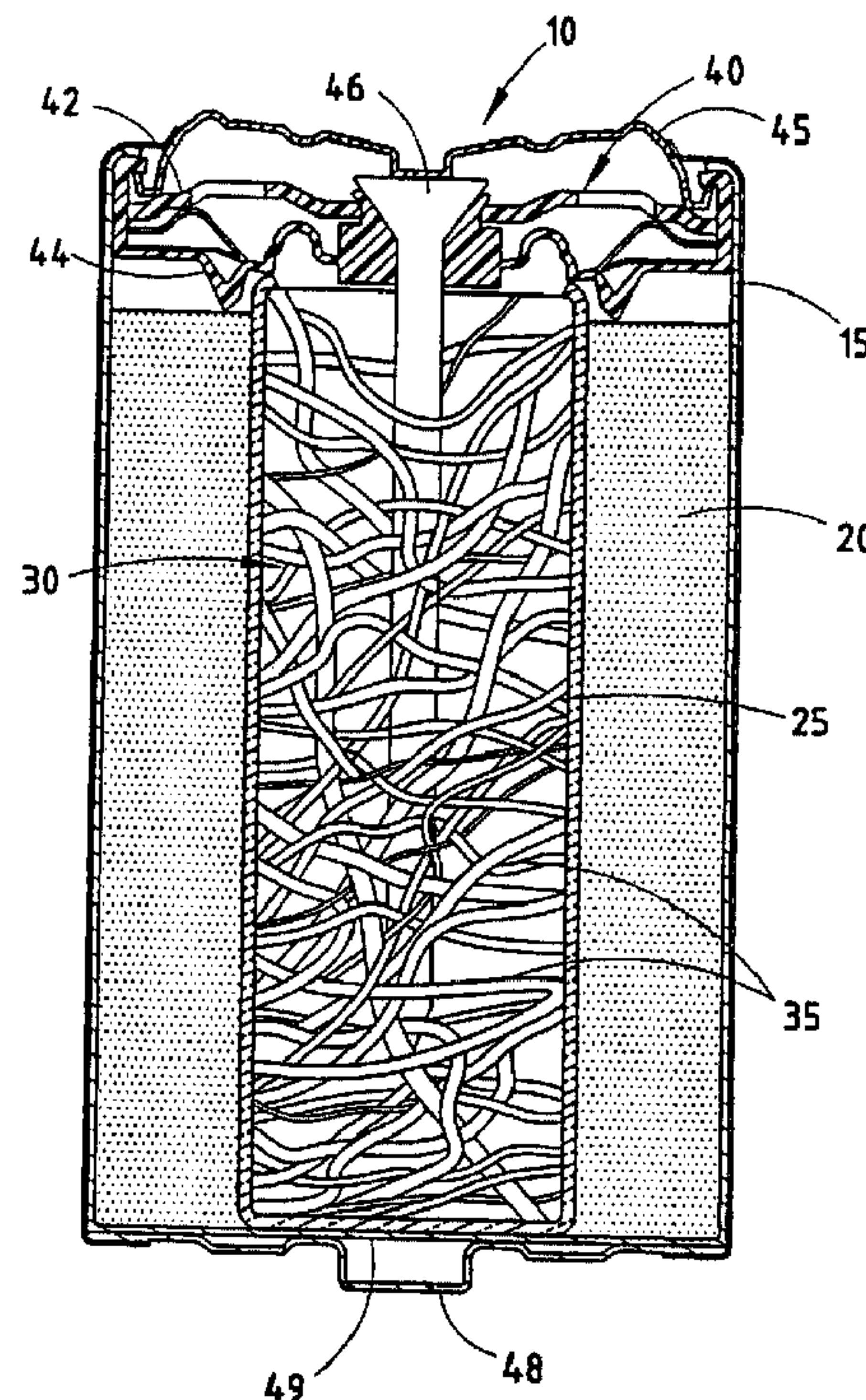




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(54) Title: ELECTRODE CONSTRUCTION FOR AN ELECTROCHEMICAL CELL



(57) **Abrégé/Abstract:**

An electrode is provided that includes at least one ribbon of electrochemically active material. By forming a negative electrode of zinc ribbons, the high-rate discharge capacity of the negative electrode is significantly increased. Consequently, the high-rate service of an electrochemical cell having the inventive electrode structure is improved.



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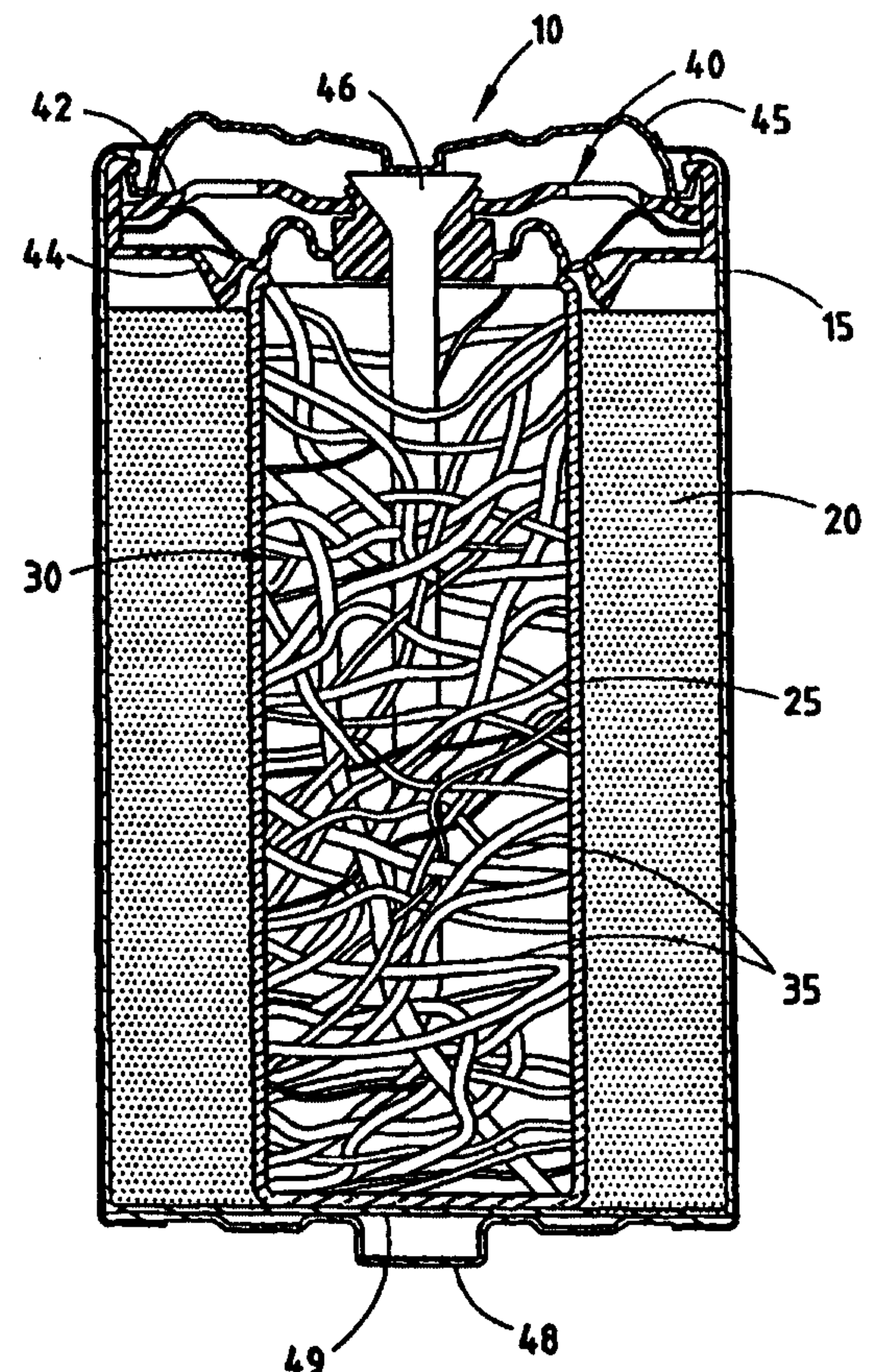
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## (57) Abstract

An electrode is provided that includes at least one ribbon of electrochemically active material. By forming a negative electrode of zinc ribbons, the high-rate discharge capacity of the negative electrode is significantly increased. Consequently, the high-rate service of an electrochemical cell having the inventive electrode structure is improved.





ELECTRODE CONSTRUCTION FOR AN ELECTROCHEMICAL CELL

5

The present invention generally relates to an electrochemical cell. More particularly, the present invention relates to an improved electrode for an electrochemical cell, particularly an alkaline cell.

10

Typical alkaline electrochemical cells include a positive electrode made of manganese dioxide ( $\text{MnO}_2$ ), a negative electrode made of zinc, and an alkaline electrolyte made of potassium hydroxide (KOH), or the like. The positive electrode is normally formed as a hollow cylinder with its outer surface contacting the inner surface of a cell housing, which is shaped as a can. A separator is disposed within the inside of the positive electrode to physically separate the positive electrode from the negative electrode while allowing ionic transport between the two electrodes.

15

The negative electrode is formed by mixing the zinc active material in the form of a zinc alloy powder with the alkaline electrolyte and a gelling agent. The mix is dispensed within the hollow middle area defined by the inner surface of the separator within the positive electrode. Subsequently, a collector assembly is inserted into the open end of the cell housing, with a collector nail extending down within the negative electrode/electrolyte gel. An outer cover is then placed over the collector assembly, and the cell housing walls are then crimped over the outer cover to seal the cell.

20

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JP-A-7254406 discloses the use of a gelled zinc negative electrode in which a gelling agent and alkaline electrolyte are mixed, and the negative electrode active material comprises non-amalgamated zinc powder in the shape of spheres and elongated elements to increase the surface area exposed to alkali electrolyte. The

30

elongated powder, however, is relatively short in comparison to the dimensions of the negative electrode.

In the manufacture and use of these known batteries or cells, the lowest zinc  
5 volume percent in the negative electrode that manufacturers utilise is about no less  
than 28 percent in the negative electrode gel in order to both match the positive  
electrode's rate of electrochemical output and provide sufficient particle-to-particle  
and particle-to-collector contact to maintain the negative electrode's electrical  
conductance. Below this amount, voltage instability occurs as well as the resulting  
10 production of a cell structure having high sensitivity to shock and vibration, which  
causes the zinc particles to migrate away from the current collector nail thereby  
decreasing cell efficiency.

In order to provide the maximum electrochemical activity and a minimum of  
15 limiting polarisation, it is desirable to operate a battery at as low a current density as  
possible while still producing the required amount of total current from the system.  
Accordingly, alkaline batteries conventionally employ electrodes made from  
powdered active materials to obtain the highest possible surface area per unit weight  
or volume, and thus minimise the current density.

20

Conventional zinc powder is powder that has been produced by air-jet  
atomisation of molten zinc. It consists of irregularly shaped particles, ranging from  
lumpy or distorted spheroids to elongated, tuberous forms. In typical battery grade  
zinc powder, the full population of material consists of many individual particles of a  
25 wide range of sizes and shapes. The median value of the particle size for negative  
electrodes, as determined by sieving, is approximately 100 to 300  $\mu\text{m}$ . The extremes  
of particle sizes range from 20 to 1000  $\mu\text{m}$ .

US-A-3,853,625 discloses a gel-free negative electrode made of zinc fibres  
30 and needles. The zinc fibres and needles are disclosed as having a 150  $\mu\text{m}$  (0.006-  
inch) diameter and lengths between 3 mm (one eighth of an inch) and 10 cm (four



inches). The fibres and needles are disclosed as being formed as a self-supporting mat with the zinc uniformly distributed throughout the negative electrode.

While zinc powder negative electrodes are relatively efficient at low discharge rates, such electrodes are much less efficient when discharged at high rates. Given that most new battery-powdered devices have high current demands, causing the batteries to discharge at high rates, there exists a strong demand for batteries having greater high-rate performance.

10 In WO-A-9820569, a negative electrode is disclosed that includes zinc flakes. The zinc flakes differ from the prior zinc powder particles in that the zinc flakes have a thickness many times smaller than both their length and width, for example, 10 to 20 times smaller. The disclosed flakes have a thickness on the order of 25  $\mu\text{m}$  (0.001 inch) and lengths and widths of 0.6 to 1 mm (0.024 to 0.04 inch). While the use of  
15 zinc flakes improves the high-rate performance of the negative electrode of an alkaline electrochemical cell, there remains room for further improving negative electrode performance, particularly at high drain rates.

It has been discovered that discharge of zinc in an alkaline cell starts near the  
20 positive electrode and then proceeds away from the positive electrode. Because the reaction product (*e.g.*, zinc oxide and zinc hydroxide) resulting from the discharge of zinc is more voluminous than the zinc itself, a reaction product skin tends to form between the positive and negative electrodes if there is not enough space to accommodate the reaction product. While such a skin still allows some electrolyte to  
25 pass through, the reacting zinc behind the skin does not receive hydroxyl ions from where they are formed in the positive electrode fast enough to offset those consumed by the reacting zinc. Consequently, polarisation occurs leading to premature cell failure.

30 In most cell designs, the current collector, which is often in the form of a nail, is located in the centre of the negative electrode. Because most of the zinc discharge

occurs at the outer periphery of the negative electrode near the positive electrode interface, it is necessary to maintain a continuous path of connected zinc from the reacting site to the collector nail to facilitate electron transfer. When zinc powders or flakes are used, many particles must touch to form an electron conduction path back to the collector nail. However, because the zinc powder or flakes only constitute approximately 30 percent of the negative electrode volume, any physical shocks to the cell may cause the particles to shift and lose contact. Thus, excess zinc is often added to the negative electrode only to serve as an electron conductor. The excess zinc, however, is not discharged during the life of the cell and takes up valuable space within the cell that could otherwise be used for extra electrolyte to fuel reactions or to hold discharge reaction product while still leaving space for ion transfer. Alternatively, some of the space could be used to increase the amount of  $\text{MnO}_2$  in the positive electrode.

The above-noted problem of maintaining an electron conduction path is further exasperated as the cell discharges and zinc is consumed in the redox reaction. Although zinc fibres or needles generally provide for a better conduction path than zinc flakes or zinc powder, the fibres and needles are too thin to maintain their physical structure throughout discharge, and hence, electron conductivity is not readily maintained. The lack of a gelling agent in such an electrode structure allows the zinc structure to fall apart and move within the negative electrode volume. Such movement does not provide for efficient distribution and discharge near the end of the battery's useful life.

We have now found that some or all of the disadvantages associated with the prior art can be overcome by an electrode construction in accordance with the present invention.

Accordingly, in a first aspect, the present invention provides an electrochemical cell comprising:

a cell housing having an interior surface;



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a first electrode disposed adjacent the interior surface of the cell housing, the first electrode defining a cavity;

a second electrode disposed within the cavity;

a separator disposed between the first and second electrodes; and

5 an electrolyte disposed in the cell housing,

wherein at least one of the electrodes includes at least one ribbon of electrochemically active material having a length of at least about 2 mm and extending near the separator interface.

10 In a second aspect, the present invention provides a negative electrode for an alkaline cell, the negative electrode comprising zinc ribbons that have a length of at least about 2 mm and extend near the separator interface and having a discharge capacity of greater than 541 mAh/g when discharged continuously at a current of 250 mA per gram of zinc composition.

15

It is an advantage of the present invention that there can be provided a zinc negative electrode for an alkaline cell having improved performance. More specifically, the present invention can provide a zinc negative electrode having significantly increased discharge capacity at high discharge rates. Correspondingly, it is also an advantage of the present invention that an alkaline electrochemical cell can be provided including the improved zinc negative electrode.

20

As used and described herein, a "ribbon" is an elongated flexible element with a width substantially greater than its thickness and a length substantially greater than its width. Preferably, such a ribbon has a width that is at least three times its thickness and a length at least three times its width.

25

The ribbons preferably have a length that exceeds the radial distance between the current collector and the inner surface of the separator between the electrodes. More preferably, the ribbons have lengths that are at least about 10 times the radial distance between the current collector and the inner surface of the separator to ensure

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that the ribbons will extend near the separator interface and still physically contact the current collector. Thus, the length of the ribbons is at least 2 mm and is preferably at least 2 cm, and may be selected according to the dimensions of the



cell. It will be appreciated, however, that the length of the ribbons is not critical and the length of each of the ribbons may vary.

By physically contacting the current collector, the ribbons maintain a direct  
5 electrical connection. Moreover, the ribbons provide a conduction path that is stable and not subject to physical shock. In addition, by using the negative electrode construction according to an embodiment of the present invention, the electrolyte is wicked towards the centre of the negative electrode and reaction product is allowed to move, thereby avoiding the formation of an undesirable skin at the negative-positive  
10 electrode interface. The solid ribbons also eliminate problems associated with metal particles migrating through the separator or otherwise becoming located on the wrong side of the separator and in contact with the positive electrode.

Although a plurality of such ribbons is described and illustrated, it will be  
15 appreciated that an extra long single ribbon may be used. The length and number of the ribbons is only limited by the weight of zinc or other electrode metal to be added. Also, if more than one ribbon is used, the dimensions of each ribbon may vary.

For an alkaline cell, the ribbons are preferably made of zinc, and are  
20 preferably made of a zinc alloy including one or more of the metals selected from bismuth, indium, calcium, and aluminium. Zinc ribbons may, for example, be formed by rapid solidification of molten zinc alloy. Such zinc ribbon is now available from Transmet of Columbus, Ohio. Other ribbon forming techniques may be used, as desired.

25

However, although the present invention is primarily described herein as a primary alkaline cell, it will be appreciated that the inventive electrode structure may be utilised in other primary cell chemistries, such as carbon-zinc or lithium cells, or in rechargeable cells, such as nickel cadmium, nickel metal hydride, or lithium-ion  
30 cells. Thus, the ribbons could be made of any of the electrochemically active materials used for the positive or negative electrodes in such cells. For example, the

ribbons could be made of a compound including at least one material selected from the group consisting of cadmium, nickel, metal hydride, lithium, cobalt,  $\text{MnO}_2$ , zinc, and carbon. Therefore, the ribbons used in accordance with the present invention may be made of electrode metals and metal alloys other than zinc or zinc alloy, and  
5 can be chosen by those skilled in the art according to the desired cell type and chemistry.

By making the ribbons between about 2 and 80  $\mu\text{m}$  thick, and more preferably approximately 20 to 25  $\mu\text{m}$  thick, the ribbons will not disintegrate before the cell fully  
10 discharges, but instead will retain their ribbon-like form and, importantly, the ribbons maintain an excellent conductive path to the current collector. The width of the electrode is selected to maintain electrical continuity throughout the useful life of the battery to provide sufficient structural integrity so that the ribbon is self-supporting, and to allow ease of dispensing the ribbon in the cavity of the positive electrode. The  
15 width of the ribbons is preferably between about 40 and 3200  $\mu\text{m}$ , and is more preferably about 500  $\mu\text{m}$ .

Given the self-supporting nature of the negative electrode construction, use of a gelling agent in the electrolyte may be avoided since it is not needed to support the  
20 zinc or other electrode metal. Thus, the distribution of the zinc, or other metal, throughout the negative electrode may be maintained. Because such a gel-free electrolyte is much less viscous, it is more easily dispensed in the cell and air is less likely to become trapped within the negative electrode during manufacture. If desired, gelled electrolyte could nevertheless be subsequently added.

25

It will be appreciated that, while the present invention has been described as a negative electrode, it is possible that the electrode having the inventive ribbon(s) could be the positive electrode.

30

Also, although the present invention is shown and described primarily with reference to cylindrical cells, it will be appreciated by those skilled in the art that the



zinc negative electrode of the present invention may be employed in other electrochemical cells, such as prismatic cells. Additionally, the negative electrode of the present invention may be used in cells having essentially any cell construction.

5 For an alkaline cell, the positive electrode may for example be made primarily manganese dioxide ( $\text{MnO}_2$ ). The electrolyte is then an alkaline electrolyte such as potassium hydroxide (KOH). As mentioned, other cell components may be used to make up cells according to the present invention, as may be selected by those skilled in the art. In a preferred embodiment, however, the negative electrode comprises  
10 ribbons of zinc or zinc alloy, the positive electrode is made of primarily  $\text{MnO}_2$  and the electrolyte is KOH solution.

By maximising the metal surface area and by maintaining an excellent conductive path between the metal ribbons and current collector, the high-rate  
15 discharge capacity of the negative electrode remarkably improves.

The zinc ribbons used in the present invention have excellent wetting capability and enable the replacement of electrolyte hydroxyl ions at the surface of the zinc negative electrode by actually drawing electrolyte absorbed in the positive  
20 electrode back through the separator to the negative electrode where the electrolyte is needed using a capillary-like action.

In one embodiment, there is provided a composition including zinc for use in a negative electrode of an electrochemical cell having a discharge efficiency of greater  
25 than 66 percent when discharged continuously at a current of 250 mA per gram of the composition. Preferably, the composition has a discharge efficiency of at least about 88 percent when discharged continuously at a current of 250 mA per gram of the composition. In another embodiment, there is provided a composition including zinc for use in a negative electrode of an electrochemical cell having a discharge capacity  
30 of greater than 541 mAh/g when discharged continuously at a current of 250 mA per gram of the composition. Preferably, the composition has a discharge capacity of at

least about 730 mAh/g when discharged continuously at a current of 250 mA per gram of the composition. In these two embodiments, the composition preferably includes a zinc alloy, more preferably a zinc alloy that includes at least one of the metals selected from bismuth, indium, calcium, and aluminium.

5

In another embodiment, a negative electrode for an alkaline cell is provided, the negative electrode comprising a zinc composition and having a discharge capacity of greater than 541 mAh/g when discharged continuously at a current of 250 mA per gram of zinc composition. Preferably, the negative electrode has a discharge capacity  
10 of at least about 730 mAh/g when discharged continuously at a current of 250 mA per gram of zinc composition. In another embodiment, a negative electrode for an alkaline cell is provided, the negative electrode comprising a zinc composition and having a discharge efficiency of greater than 66 percent when discharged continuously at a current of 250 mA per gram of zinc composition. Preferably, the negative  
15 electrode has a discharge efficiency of at least about 88 percent when discharged continuously at a current of 250 mA per gram of zinc composition. In these two embodiments, preferably the zinc composition is a zinc alloy, more preferably a zinc alloy that includes at least one of the metals selected from bismuth, indium, calcium, and aluminium. Preferably, the zinc composition is provided in the form of a ribbon.

20

The present invention will be further understood by reference to the following description and drawings, in which:

Figure 1 is a cut-away schematic of an electrochemical cell constructed in accordance with a first embodiment of the present invention; and

25 Figure 2 is a line graph showing comparative discharge efficiencies for conventional negative electrodes and negative electrodes constructed in accordance with the present invention.

Figure 1 shows an electrochemical cell 10 constructed in accordance with a preferred embodiment of the present invention. As shown, cell 10 includes a  
30 cylindrical cell housing 15 in which a positive electrode 20 is located adjacent the



10

inner sidewalls of cell housing 15. Positive electrode 20 is shaped as a hollow cylinder that may be impact moulded inside of housing 15 or inserted as a plurality of rings after moulding. In a typical alkaline cell, positive electrode 20 is made primarily of  $\text{MnO}_2$ . Cell 10 further includes a separator 25 that lines the inner walls  
5 of the hollow cavity within positive electrode 20. As described in further detail below, a negative electrode 30 is deposited within the separator-lined hollow cavity of positive electrode 20. An alkaline electrolyte, such as KOH, is also dispensed within the lined hollow cavity of positive electrode 20.

10 The cell is closed and sealed by a collector assembly 40 and an outer terminal cover 45. In general, collector assembly 40 includes an inner cover 42, a seal 44, and a current collector 46. As known in the art, collector assembly 40 and outer terminal cover 45 are electrically coupled to negative electrode 30 and are insulated from the remainder of cell housing 15. In this manner, outer terminal cover 45 may  
15 serve as a negative contact terminal for cell 10. A second outer terminal cover 48 may be secured to a closed end 49 of the electrically conductive cell housing 15 to serve as a positive terminal for cell 10.

As shown in Figure 1, negative electrode 30 includes a plurality of ribbons 35  
20 of electrochemically active material. The ribbons 35 are elongated flexible elements with a width substantially greater than its thickness and a length substantially greater than its width. For an alkaline cell, ribbons 35 are made of zinc, more preferably of a zinc alloy including one or more of the metals selected from bismuth, indium, calcium, and aluminium. As shown, ribbons 35 have a length that exceeds the radial  
25 distance between current collector 46 and the inner surface of separator 25, and preferably have lengths that are at least about 10 times the radial distance between current collector 46 and the inner surface of separator 25 to ensure that the ribbons will extend near the separator interface and still physically contact current collector 46. By physically contacting current collector 46, the zinc ribbons maintain a direct  
30 electrical connection. By maximising the zinc surface area and by maintaining an

excellent conductive path between the zinc ribbons and current collector 46, the high-rate discharge capacity of the negative electrode remarkably improves.

### EXAMPLE

5

A half-cell was used to characterise the discharge characteristics of the zinc ribbon.

10 The half-cell used was a three-electrode electrochemical system consisting of a working electrode, a cylindrical nickel-mesh counter electrode, and a commercial Hg/HgO reference electrode. The working electrode was a cylindrical nylon-mesh basket filled with anode material, either gelled zinc powder or flakes, or zinc ribbon in accordance with the present invention, in contact with a brass nail current collector. The half-cell was flooded with electrolyte of a composition of 37 percent KOH/3 percent ZnO. Discharges were conducted at ambient temperature. A  
15 constant current was delivered by a Solartron Electrochemical Interface, and electrode potentials were monitored by a data logger. The results are shown in Figure 2.

As shown in Figure 2, the theoretical discharge capacity of zinc is 820 mAh/g.

20 The discharge capacity of a half-cell including a negative electrode constructed in accordance with the present invention was found to be approximately 730 mAh/g at a high-rate discharge current of 250 mA per gram of zinc, representing a discharge efficiency of 88.9 percent of the theoretical discharge capacity.

25 The high-rate discharge capacity for a half-cell including a conventional zinc negative electrode formed by mixing zinc powder with electrolyte and a gelling agent is 336 mAh/g when discharged at 250 mA per gram of zinc, representing a discharge efficiency of 41 percent of the theoretical discharge capacity for zinc.

30 A negative electrode formed using 90 percent zinc powder and 10 percent zinc flakes as taught in WO-A-98/20569 has a discharge capacity of 541 mAh/g at a



discharge rate of 250 mA per gram of zinc, representing a discharge efficiency of 66 percent.

5       The increased discharge efficiency of the zinc negative electrode of the present invention results in an electrochemical cell having significantly improved high-rate service, which is becoming increasingly important as more and more battery-powered devices are designed that draw current at increasingly higher rates.

10       It will be understood that the embodiments shown in the drawings and described above are merely for illustrative purposes.

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**CLAIMS:**

1. An electrochemical cell comprising:  
a cell housing having an interior surface;  
5 a first electrode disposed adjacent the interior surface of the cell housing, the  
first electrode defining a cavity;  
a second electrode disposed within the cavity;  
a separator disposed between the first and second electrodes; and  
an electrolyte disposed in the cell housing,  
10 wherein at least one of the electrodes includes at least one ribbon of  
electrochemically active material having a length of at least about 2 mm and extending  
near the separator interface.
2. An electrochemical cell according to claim 1 and further including a current  
15 collector extending centrally within the cell housing, wherein the ribbon has a length  
equal to at least the distance between the separator and the current collector.
3. An electrochemical cell according to claim 2, wherein the ribbon has a length  
of at least about 10 times the distance between the separator and the current collector.  
20
4. An electrochemical cell according to any preceding claim, wherein the ribbon  
has a width between about 40 and 3200  $\mu\text{m}$ .
5. An electrochemical cell according to any preceding claim, wherein the ribbon  
25 has a thickness of between about 2 and 80  $\mu\text{m}$ .
6. An electrochemical cell according to any preceding claim, wherein the ribbon  
is made of a zinc alloy, including at least one of the metals selected from bismuth,  
indium, calcium, and aluminium.

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7. An electrochemical cell according to any preceding claim, wherein the electrolyte is an alkaline electrolyte.

8. An electrochemical cell according to any preceding claim, wherein the first  
5 electrode includes  $\text{MnO}_2$ .

9. An electrochemical cell according to any preceding claim, wherein the first electrode is a positive electrode and the second electrode is a negative electrode.

10 10. A negative electrode for an alkaline cell, the negative electrode comprising zinc ribbons that have a length of at least about 2 mm and extend near the separator interface and having a discharge capacity of greater than 541 mAh/g when discharged continuously at a current of 250 mA per gram of zinc composition.

15 11. A negative electrode according to claim 10, wherein the negative electrode has a discharge capacity of at least 730 mAh/g when discharged continuously at a current of 250 mA per gram of zinc composition.

20 12. A negative electrode of an alkaline cell, the negative electrode comprising zinc ribbons that have a length of at least about 2 mm and extend near the separator interface and having a discharge efficiency of greater than 66 percent when discharged continuously at a current of 250 mA per gram of zinc composition.

25 13. A negative electrode according to claim 12, wherein the negative electrode has a discharge efficiency of at least about 88 percent when discharged continuously at a current of 250 mA per gram of zinc composition.

14. A negative electrode according to any of claims 10 to 13, wherein the zinc ribbon is made of a zinc alloy.

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15. A negative electrode according to claim 14, wherein the zinc alloy includes at least one of the metals selected from bismuth, indium, calcium, and aluminium.



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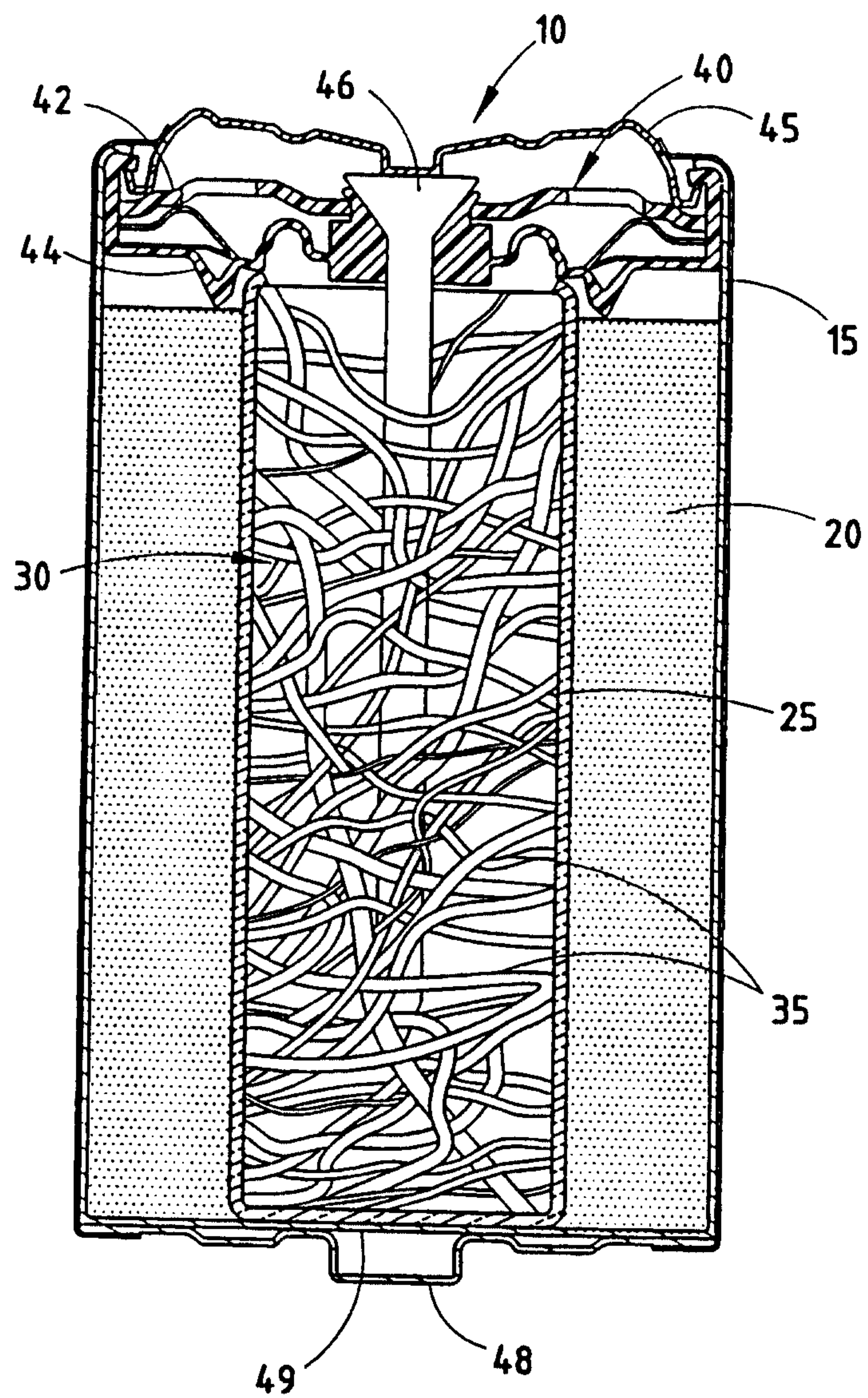


FIG. 1

Half-Cell Anodic Discharge  
of Zinc at 250mA/g Zinc

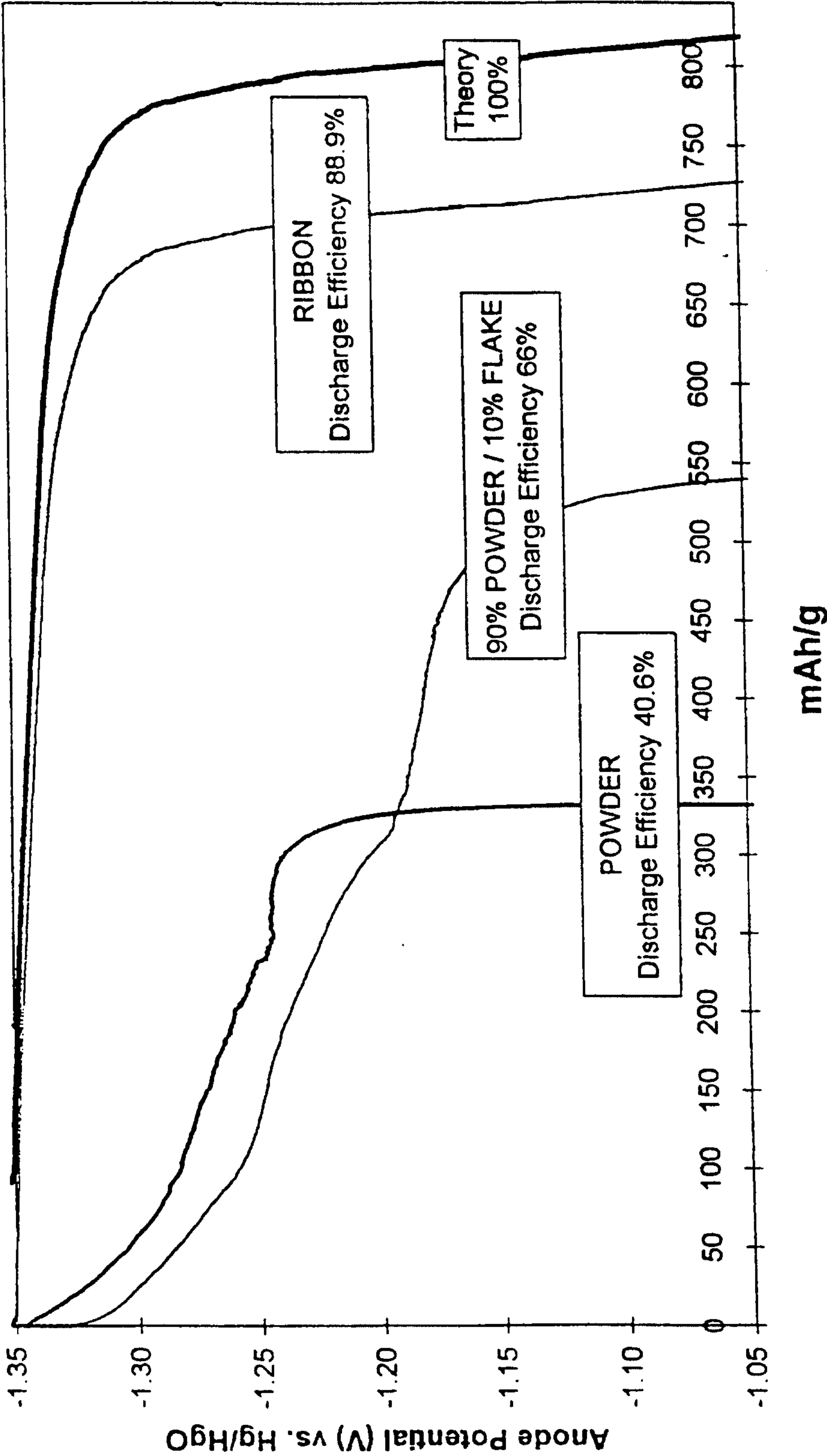


FIG. 2



