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(54) Title: METHODS AND SYSTEMS FOR MAKING BATTERY ELECTRODES AND DEVICES ARISING THEREFROM

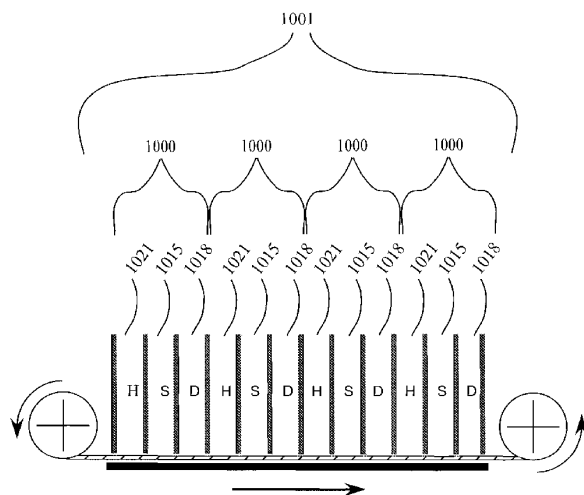


FIG 5

(57) Abstract: The invention provides, in preferred em-
bodiments, methods, systems, and devices arising there-
from for making battery electrodes, in particular, for lithi-
um-ion batteries. Unlike conventional slurry coating meth-
ods that use mechanical means to coat thick pastes of ac-
tive material, other materials, and solvent(s) onto a sub-
strate, the invention provides for a method to produce
electrode coatings onto support in a multi-layer approach
to provide highly uniform distribution of materials within
the electrode. Problems of differential sedimentation of
particles in slurries found in conventional methods are
minimized with the methods of the present invention. Also
included are systems for producing in large-scale the bat-
tery electrodes of the invention. Further included are elec-
trodes produced by the methods and systems described
herein.

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METHODS AND SYSTEMS FOR MAKING BATTERY ELECTRODES AND DEVICES
ARISING THEREFROM

FIELD OF THE INVENTION

[0001] The invention generally relates to the field of battery electrode manufacturing, preferably lithium-ion battery electrode manufacturing. The invention generally pertains to the field of energy storage, batteries, lithium-ion (Li-ion) batteries, advanced vehicles technology, and reduction of national reliance upon foreign petroleum products. The invention also relates to manufacturing systems for applying a coating or coatings to surfaces of substrates. The invention further relates to the field of energy efficiency, and environmental protection.

BACKGROUND

[0002] Lithium ion batteries play an important part in today's high-technology world. Reaching new markets, lithium ion batteries offer the promise of high energy capacity/high power output in relatively lightweight and compact formats when compared to traditional lead acid, nickel metal anhydride, or nickel cadmium batteries.

[0003] Traditional methods for making lithium ion batteries generally include the formation of a slurry comprising a solvent and a mixture of particles. The slurry is then spread out upon the surface of a substrate, typically a metal foil, then dried and calendared to a desired thickness and density. Problems exist with the slurry coating method, whether by doctor blade or by slot die process, in that generally only one layer can be deposited upon the surface of the substrate. Depositing additional layers using doctor blade and slot die methods runs the risk of delaminating the earlier deposited layers due to the forces applied against the substrate as it is pulled across the doctor blade or slot die head.

[0004] Another problem with traditional battery making methods is that because thick layers are deposited to achieve the desired energy density for the electrode, the period of time it takes for the solvent to evaporate from the deposited slurry is considerable. During this time while the slurry is wet, particles of differing sizes and rheological behavior will sediment at different rates thus causing a stratification of the soon to solidify electrode matrix. Stratification leads to less than optimal performance because the different particles within the electrode matrix are not spatially distributed evenly.

[0005] There has been a trend towards using nanometer scale sized active material particles for electrodes. Not wishing to be bound by theory, it is believed that nano-scale particles present a problem, however, because they have a greater number of particles per unit mass than micrometer scale particles typically used in commercially available cells. Unless higher than average amounts of conductive particles like carbon black are used, the increased number of active material particles increases the internal resistance of the electrode. Internal resistance causes power loss through heating and can contribute to thermal runaway and flame. Nanoparticles, however, can be used by substituting carbon nanotubes instead of or in combination with carbon black. The inside diameter of carbon nanotubes, compared to their outside dimension, greatly reduces the number of effective interfaces in the electrical conductive path. A problem exists, however, in using carbon nanotubes in that they tend to aggregate. Likewise, active material nano-scale particles tend to aggregate as well. Aggregation can pose a problem with coating surfaces to form electrodes using a slurry based process.

[0006] Accordingly, there is a need for a method for depositing materials onto a substrate for the purposes of making battery electrodes that provides for uniform distribution of particles within the electrode matrix. There is also a need for a method for depositing materials onto a substrate that avoids the need for using toxic organic chemical as a solvent. Embodiments of the invention address the above noted problems and other problems, individually and collectively.

BRIEF SUMMARY OF THE INVENTION

[0010] Among addressing other problems, it is an object of the invention to address the problems mentioned above in making advanced battery components. Towards this end, the invention aims to provide superior methods for manufacturing electrodes for use in batteries, preferably lithium ion batteries. The invention provides, in one aspect, a method for coating a substrate using multi-coat spraying. In preferred embodiments, the method comprises the steps of: providing a substrate having a surface; providing an active material suspension comprising: active material particles; and, electrically conductive particles; a solvent; spraying the active material suspension onto the substrate surface to form a first coating layer; evaporating at least 50% of the solvent, if any, from the first coating layer; repeating the steps (c) through step (e) for at least two repetitions.

[0011] In preferred embodiments, the steps (c) and (d) are repeated at least five times. In more preferred embodiments, steps (c) and (d) are repeated at least ten times. And, in highly preferred embodiments, steps (c) and (d) are repeated at least twenty times.

[0012] In certain embodiments, the active material suspension is sprayed using an aerosol sprayer, more preferably, an airless sprayer, and yet even more preferably an ultrasonic sprayer. It is highly preferred to use a pulse width modulated sprayer, and wherein the active material suspension is sprayed in a volumetrically controlled manner.

[0013] In another embodiment, the invention provides for a method wherein the evaporating step further comprises detecting the amount of solvent in the coating layer. In preferred embodiments, the coating layer is dried to a content level of about less than 20%

w/w prior to repeating the spraying step. In particularly preferred embodiments, the thickness of the coating layer is measured prior to the repeating of the spraying and evaporating steps. In some embodiments, the density of the coating layer is measured prior to the repeating of the spraying and evaporating steps.

[0014) In highly preferred embodiments, the active material particles comprise a battery electrode active material. In some embodiments, the electrically conductive particles comprise carbon, more preferably, carbon comprises carbon nanotubes, and yet more preferably, carbon comprises graphitic carbon, and yet other embodiments, the carbon is carbon black. In highly preferred embodiments, the electrically conductive particles comprise a mixture of carbon particles mentioned above.

[0015) In highly preferred embodiments, the solvent is a non-organic solvent, and in some embodiments, the solvent is an organic solvent. In particularly preferred embodiments, the solvent comprises water. In some embodiments, the solvent comprises ethanol. In certain preferred embodiments, the solvent comprises acetone, and/or N-methylpyrrolidone.

[0016) In particularly preferred embodiments, the battery active material reversibly stores lithium ions.

[0017) In one aspect of the invention, the spraying step is operationally linked to a detector monitoring at least one attribute of the coating layer so that the spray volume is adapted in real-time in response to control, wholly or partly, a degree of the attribute.

[0018) In certain embodiments of the invention, the substrate is wound about an axis to form a substrate roll and the substrate is unwound from the roll and is traversed through a

spraying region wherein the first spraying step occurs. In highly preferred embodiments, the substrate first traverses through the spraying region and then traverses through a evaporating region where the first evaporating step occurs. In highly preferred embodiments, the substrate subsequently traverses through a second spraying region then a second evaporating region and so forth until a desired number of coating layers are built upon the substrate surface. In some embodiments, the substrate further comprises a second surface on a side of the substrate opposite the first substrate surface. In particularly preferred embodiments, the spraying step and the evaporating step are applied simultaneously to the first and the second substrate surfaces to form a first coating layer upon the substrate first surface and a second coating layer upon the substrate second surface to yield a double-sided coating on the substrate surfaces. In some embodiments, the spraying step and the evaporating step are applied alternately to the first and the second substrate surfaces to form a first coating layer upon the substrate first surface and a second coating layer upon the substrate second surface to yield a double-sided coating on the substrate surfaces. In some embodiments, a subsequent coating layer comprises materials different from the active material particles and the electrically conductive particles.

[0019] In preferred embodiments, the evaporating step further comprises providing a heat source, preferably where the heat source comprises an infrared heating element, and/or a where the heat source comprises a gas-catalytic heat source, and/or where the heat source comprises a radio frequency transmitter, and/or the heat source comprises a convective heat element.

[0020] In certain embodiments, the evaporating step further comprises providing an air flow apparatus for passing air across the surface of the substrate during the evaporating step, preferably where the air passing across the surface of the substrate surface is heated, and/or the air passing across the surface of the substrate is not heated, and/or the air passing across the surface of the substrate is cooled.

[0021] In some embodiments, the heat source further comprises two or more air flow apparatuses wherein at least one air flow apparatus passed heated air across a portion of the surface of the substrate at one point in time and then passes cooled air across the portion of the surface of the substrate at another point in time.

[0022] In certain embodiments, the active material particles comprise nanometer scale sized active material particles, preferably where the active material particles comprise nanostructured materials, and/or where the active material particles contain micrometer scale sized active material particles. In highly preferred embodiments, the active material particles comprise a cathode active material capable of reversibly storing an ion. In some embodiments, the cathode active material comprises a cathode active material selected from the group consisting of: LiFePO_4 ; LiCoO_2 ; LiMnO_2 ; LiMn_2O_4 ; $\text{LiMn}_{1/2}\text{Ni}_{1/2}\text{O}_2$; and, $\text{Li}(\text{Ni}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3})\text{O}_2$.

[0023] In some embodiments, the active material particles comprise an anode active material capable of reversibly storing an ion, preferably where the anode active material may be carbon; graphite; graphene; carbon nanotubes; silicon; porous silicon; nanostructured silicon; nanometer scale silicon; micrometer scale silicon; alloys containing silicon; carbon coated silicon; carbon nanotube coated silicon; tin; alloys containing tin; and/or $\text{Li}_4\text{Ti}_5\text{O}_{12}$.

In highly preferred embodiments, the active material particles further comprise lithium ions stored therein.

[0024] In some embodiments, the electrically conductive particles comprise carbon, whereas in some embodiments, the electrically conductive particles comprise at least one metal element. In certain embodiments, the carbon may be carbon; amorphous carbon; carbon black; carbon nanotubes; single-walled carbon nanotubes; multi-walled carbon nanotubes; carbon nanorods; carbon nanofoam; nanostructured carbon; carbon nanobuds; Buckminster fullerenes; linear acetylenic carbon; metallic carbon; Lonsdaleite; diamond; graphite; and/or , graphene.

[0025] In certain embodiments, the metal element may be ruthenium; rhodium; palladium; silver; osmium; iridium; platinum; and/or, gold.

[0026] In preferred embodiments, the solvent comprises water, the solvent comprises an organic solvent, and/or the solvent comprises a mixed solvent comprising at least two different solvents. In certain embodiments, the solvent may be a polar solvent, polar aprotic solvent; and/or, a non-polar solvent. In some embodiments, the solvent may be water; methanol; ethanol; propanol; isopropanol; butanol; tert-butanol; pentane; hexane; heptane; acetone; dimethylformamide; n-methyl-2-pyrrolidone; and/or, 1,3-dimethyl-2-imidazolidinone.

[0027] In some embodiments, the substrate comprises a metal, a non-metal, or both. In certain embodiments, the substrate comprises a woven material, a non-woven material, or both. In some embodiments, the substrate is porous or non-porous, or comprises both porous

and non-porous portions. In particularly preferred embodiments, the substrate is a foil. In some embodiments, the substrate comprises a film. In certain embodiments, the substrate comprises a plurality of layers, preferably two or more of the plurality of layers are different, and/or two or more of the plurality of layers are the same. In highly preferred embodiments, the substrate comprises copper, aluminum, or both.

[0028] The invention provides, in another aspect, a system for making a battery electrode comprising: an unwinder; a rewinder; a plurality of spray/dry regions disposed between the unwinder and the rewinder, each spray/dry region comprising: a sprayer in liquid communication with a liquid suspension source; a dryer in fluid communication with a gas source, the dryer being immediately preceded the spray region.

[0029] In preferred embodiments, the plurality of spray/dry regions comprises at least two spray/dry regions. In even more preferred embodiments, the plurality of spray/dry regions comprises at least five spray/dry regions. In still more preferred embodiments, the plurality of spray/dry regions comprises at least ten spray/dry regions. In particularly preferred embodiments, the plurality of spray/dry regions comprises at least twenty spray/dry regions.

[0030] These and other embodiments of the invention are described in further detail below with reference to the Figures and the Detailed Description

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0031) FIGURES 1A and 1B depict a substrate traversing from a spraying region to a drying region in an embodiment of the invention.

[0032) FIGURE 2 depicts a roll-to-roll spray/dry embodiment of the invention.

[0033) FIGURE 3 depicts a roll-to-roll multiple spray/dry region embodiment of the invention.

[0034) FIGURE 4 depicts a roll-to-roll multiple spray/dry/cool embodiment of the invention.

[0035) FIGURE 5 depicts a roll-to-roll multiple heat/spray/dry embodiment of the invention.

[0036) FIGURE 6 depicts a typical pulse wave signal used to control a pulse-width modulated spray head embodiment of the invention.

[0037) FIGURES 7A and 7B depict a preferred spray head of the invention in two different states.

[0038) FIGURES 8 depicts an ultrasonic multi-orifice spray head employed in a preferred embodiment of the invention.

[0039) FIGURE 9 depicts a flow-chart showing the logic flow of a feedback-loop operated spray deposition system of a preferred embodiment of the invention.

- [0040] FIGURES 10A – 10C depict images of sample electrodes produced using a preferred method of the invention.
- [0041] FIGURES 11A – 11C depict scanning microscopic images of sample electrodes produced using a preferred method of the invention.
- [0042] FIGURE 12 depicts charge/discharge curves graphically for a sample electrode produced using a preferred method of the invention.
- [0043] FIGURES 13A – 13B depict a capacity profile for two sample electrodes produced using a preferred method of the invention.
- [0044] FIGURE 14 depicts a voltage v. time profile for a sample electrode produced using a preferred method of the invention.
- [0045] FIGURE 15 depicts charge v. current profiles for two sample electrodes produced using a preferred method of the invention and a commercially available electrode.
- [0046] FIGURE 16 depicts a capacity v. current profile for two sample electrodes produced using a preferred method of the invention.
- [0047] FIGURE 17 depicts a capacity v. half-cycle number graph for two sample electrodes produced using a preferred method of the invention.
- [0048] FIGURE 18 depicts a scanning electron micrograph of a sample electrode produced using a preferred method of the invention.

[0049) FIGURES 19A – 19B depict images of sample electrodes produced using a preferred method of the invention.

[0050) FIGURE 20 depicts a voltage v. time profile for a sample electrode produced using a preferred method of the invention.

[0051) FIGURE 21 depicts charge and discharge curves for a sample electrode produced using a preferred method of the invention.

[0052) FIGURES 22A – 22B depict capacity v. half-cycle number graphs for two sample electrodes produced using a preferred method of the invention.

[0053) FIGURE 23 depict a power curve for two sample electrodes produced using a preferred method of the invention.

[0054) FIGURE 24 depicts a power curve for two sample electrodes produced using a preferred method of the invention and a commercially available electrode.

DETAILED DESCRIPTION OF THE INVENTION

[0055] The invention provides for methods for making battery electrode and systems, apparatuses for making battery electrodes and devices arising there from. Preferred embodiments of the invention provides for methods, systems, and apparatuses for making electrodes for use in lithium-ion batteries.

[0056] The invention provides for, in one aspect, for a coating system that sprays a suspension of battery electrode materials onto a substrate, preferably a metal foil substrate. The preferred embodiments of the invention differ from the prior art in at least one fundamental way. These embodiments build up an electrode matrix in numerous layers rather than by one relatively thick slurry coating. The problem with the latter includes, but is not limited to differential sedimentation of electrode materials (particle) during the drying process that creates an electrode having an inhomogeneous composition with respect to the thickness dimension of the coated electrode.

[0057] Currently, there is a trend towards using smaller and smaller sized active material particles in battery electrodes for lithium-ion cells. Not wishing to be bound by theory, the inventors believe that as the particle size lessens, the tendency for the particles to aggregate and sediment out of the wet curing electrode made by slurry coating will result in losing the benefits of the smaller sized particles, for example, but not limited to, higher surface area to mass ratio and better ion diffusion rates. Moreover, it is believed that differential sedimentation causes inefficient distribution of conductive materials and active materials within the electrode matrix thus causing some parts of the electrode matrix to have lower

conductivity than others while yet other parts of the electrode matrix have different amounts and characteristics of active material particles.

[0058) To address these problems, and others, applicants have invented a system that provides for a higher level of intra-electrode homogeneity when compared to standard slurry coating methods using one-step doctor blade or slot die type application of the electrode coating to the substrate foil current collector. By applying thin layers by spray and rapidly drying each layer, a plurality of layers of electrode material are built up to form an electrode matrix having a high degree of homogeneity with respect to spatial particle distribution and minimized homo-particle aggregation.

[0059) Turning now to FIGURE 1A, an exemplary embodiment of the invention is shown. Spray/Dry System **1000** operates by traversing Substrate **1010** from Spraying Region **1015** to Drying Region **1018**. Spraying Region **1015** and Drying Region **1018** are separated from each other and external of Spray/Dry System **1000** by several Partitions **1040**. Sprayer **1050** is supported inside Spraying Region **1015** and aimed towards Surface **1020** of Substrate **1010**. Adjacent Spraying Region **1015** is Drying Region **1018** having therein Dryer **1080** in fluid communication with Dryer Manifold **1090** and Dryer Jets **1100**.

[0060) Substrate **1010** is introduced into Spray System **1000** by way of Support Stage **1030** that passes under Partitions **1040** with Substrate **1010** thereupon. Once in Spray Region **1015**, a coating is applied to Surface **1020** of Substrate **1010** by Sprayer **1050**. Sprayer **1050** comprises Spray Tip **1060** from which Spray Mist **1070** emanates therefrom and travels towards Surface **1020** to form a layer of electrode material.

[0061) Depicted in FIGURE 1B, Substrate **1020** traverses into Dryer Region **1018**, Hot Air or Gas **1120** of Dryer Flow **1130** is passed through Dryer **1080** and Dryer Manifold **1090** out towards Surface **1020** of Substrate **1010**. After impinging upon Surface **1010**, the Hot Air or Gas **1120** is deflected upward and is scavenged from Dryer Region **1018** through Exhaust **1150** as Exhaust Flow **1055**. After Substrate **1010** Surface **1020** is sufficiently dried, Substrate **1010** is traversed out of Dryer Region **1080** upon Support Stage **1030** onward to potentially further spray/dry steps or onto some other processing.

[0062) In highly preferred embodiments, the invention provides for a continuous coating system that relies on roll-to-roll type material handling similar to that of newspaper printing presses. FIGURE 2 depicts a roll-to-roll spray/dry embodiment of the invention wherein Spray System **1000** is equipped with Unwinder **1160** and Rewinder **1190** where supported thereon are Unwind Roll **1170** and Rewind Roll **1200** loaded with Continuous Substrate **1210** that is in the form of a long ribbon-like material that arrives at Sprayer System **1000** wound upon Unwind Roll **1070** and wherein Continuous Substrate **1210** traverses Spray System **1000** ultimately terminating on Rewind Roll **1200** wherein Continuous Substrate **1210** is wound thereupon during a coating run. When finished, Rewind Roll **1200** should have wound thereabouts Continuous Substrate **1210** with Surface **1020** coated with electrode material. The continuous process generally has both Spray **1050** and Dryer **1080** active simultaneously or near simultaneously.

[0063) In highly preferred embodiments, the invention provides for a continuous coating system similar to that depicted in FIGURE 2, except that a plurality of Spray Systems **1000** are arranged serially between Unwinder **1160** and Rewinder **1190** to form Spray Line **1001**.

[0064) FIGURE 3 depicts a roll-to-roll multiple spray/dry region embodiment of the invention. Each Spraying Region **1015** and Drying Region **1018** is arranged in alternating fashion to permit multiple layers to be applied to Surface **1020** of Continuous Substrate **1210**. The rate for which Continuous Substrate **1210** is fed through Spray Line **1001** is preferably set to a speed wherein a substantial amount of solvent is removed from the coating prior to each subsequent coating cycle. This is believed to help minimize segregation of particles within the electrode coating during the drying process. In certain embodiments, a preceding layer is allowed to dry to a point that sedimentation is substantially halted even though some amount of solvent may still be present within the preceding layer prior to applying a subsequent layer of electrode material.

[0065) FIGURE 4 depicts a roll-to-roll multiple spray/dry/cool embodiment of the invention. In some embodiments, it may be desirable to reduce the temperature of Surface **1020** prior to spraying on an additional layer of electrode material. This is to ensure that the freshly sprayed material has some period of time in liquid form to self level. If dried prematurely due to Surface **1020** being too hot from a preceding drying step, Cooling Region **1019** may be further incorporated into the Spray Line **1001** depicted in FIGURE 3. Here, Spraying Region **1015** is followed by Drying Region **1018**, and then by Chilling Region **1019** wherein the temperature of Surface **1020** is lowered to a desired level to facilitate spraying in a subsequent Spraying Region **1015**.

[0066) FIGURE 5 depicts a roll-to-roll multiple heat/spray/dry embodiment of the invention. In some embodiments, it may be desirable to reduce the temperature of Surface **1020** prior to spraying on an additional layer of electrode material. This is to ensure that the

freshly sprayed material has some period of time in liquid form to self level. If dried prematurely due to Surface **1020** being too hot from a preceding drying step, Heating Region **1021** may be further incorporated into the Spray Line **1001** depicted in FIGURE 3. Here, Spraying Region **1015** is preceded by Heating Region **1021**, and then by Drying Region **1018** wherein the temperature of Surface **1020** is raised to a desired level.

[0067] In certain embodiments, Sprayer **1050** is controlled in a pulsatile manner to control flow rates without altering spray patterns. FIGURE 6 depicts a typical pulse wave signal used to control a pulse-width modulated spray head embodiment of the invention. Pulse Train **1220** comprises a series of voltage pulses organized in Pulse Trains **1240**, Pulse Train Intervals **1290**, and Pulse Profiles **1250**. Within a Pulse Train **1240** are Pulses **1280** having a time dimension width between the leading edge of Pulse **1280** and the trailing edge of Pulse **1280**, a Pulse Interval **1260** having a time dimension width between the trailing edge of a preceding Pulse **1280** and the leading edge of a immediately subsequent Pulse **1280**, and Frequency **1270** having a time dimension width between the leading edge of two consecutive Pulses **1280**. Each Pulse **1280** has Amplitude **1230** which can represent voltage amplitude or current flow.

[0068] As depicted in FIGURE 7A, in preferred embodiments, Spray System **1000** comprises a Pulse-Width Modulated ("PWM) Sprayer **1300** to precisely regulate coating flow rates while maintaining a consistent Spray Pattern **1445**. Pulse-Width Modulated Sprayer **1300** comprises: Spray Head **1310** that includes, but is not limited to, Valve Body **1340** having associated therewith: Solenoid Actuator **1350** housing Coil **1360** and a portion of Plunger **1370**; Spray Nozzle **1320** with Spray Guides **1330**. Coil **1360** is in electrical

communication through Leads **1380** with Pulse Generator **1390** that produces electrical pulses that actuate Solenoid Actuator **1350** to move Plunger **1370** into and out of Valve Body **1340** thus permitting and restricting the flow of coating suspension through Spray Head **1310** and forming Spray Pattern **1445**. Tank **1400** is in fluid communication with Spray Head **1310** through Delivery Tube **1420**. Coating Suspension, not shown, can be pumped to Spray Head **1310** using any pumping system. FIGURE 7A depicts a gas pressure pumping system wherein Tank **1400** is placed under gas pressure from a pressurized gas source through Pressurized Gas Tube **1410** to act as a gas spring to force the coating suspension in Tank **1400** through Delivery Tube **1420** to Spray Head **1310**. In FIGURE 7A, Plunger **1370** is shown in the actuated position where a portion of Plunger **1370** is urged into Valve Body **1340** to stop the flow of coating suspension through Spray Head **1310**. FIGURE 7B depicts Plunger **1370** in a retracted position that permits flow of coating suspension through Spray Head **1310** and Spray Nozzle **1320** to emit Spray **1440** forming Spray Pattern **1445** to coat a substrate, not shown. In certain embodiments, Tank **1400** may further include a device for mixing a suspension contained therein. In preferred embodiments, the mixer employs sonication and/or ultrasonication. In some embodiments, the mixer may include an impeller and/or mixing paddle.

[0069) FIGURE 8 depicts an ultrasonic multi-orifice spray head employed in a preferred embodiment of the invention. Ultrasonic Spray Head **1500** comprises, in preferred embodiments, Spray Body **1510** preferably has an internal flow control valve therein, not shown. Attached to Spray Body **1510** is Piezo Element **1520** to which Nozzle Array **1530** is attached thereto. Nozzle Array **1530** is in fluid communication with Spray Body **1510** such that when coating suspension is pumped into Spray Body **1510**, and the valve, if any, is open,

coating suspension can flow to Nozzle Array **1530** to be emitted through a plurality of Ports **1540**. Piezo Element **1520** is energized by a power source to cause Piezo Element **1540** to experience the reverse piezo electricity effect achieving a volumetric displacement along an axis perpendicular to Nozzle Array **1530**. The result is that Nozzle Array **1530** is moved back and forth along the axis perpendicular to Piezo Element **1540**. In preferred embodiments, Piezo Element **1520** is energized and de-energized by the power source at frequencies between 10,000 Hz and 100,000 Hz. By varying the frequency applied to Piezo Element **1520**, different drop sizes may be achieved for a given viscosity and pressure of the coating suspension. In preferred embodiments, strain-thinning coating suspensions are used to provide low viscosity under pressure and high viscosity once deposited upon a substrate. In some embodiments, the valve body is instead simply a body to permit flow of fluid and to support other parts of the spray head. In some embodiments, the Piezo element is located inside the valve body with a tube for transporting coating suspension to a nozzle and the element, in conjunction with the tube, act to pump and control the flow of coating suspension towards the nozzle or nozzles.

[0070] FIGURE 9 depicts a flow-chart showing the logic flow of a proportional–integral–derivative controller (PID controller) feedback-loop operated spray deposition system of a preferred embodiment of the invention. The PID controller initially sets the first 75 percent of the spray regions to apply 75 percent of the final density specified for the coating. To establish a baseline for the substrate's density, the substrate's density is measured prior to spray coating. Then, after the substrate has passed through 75 percent of the spray regions, a second (interim) density measurement is made. From the second density measurement, the first density measurement is subtracted to determine the density of the coating thus far

applied. The substrate is then coated at the pre-set flow rate to achieve the specified density. If the density of the coating thus far is too low, the flow rate of the final 25 percent of the spray regions is increased to provide for a final density according to specification. Also, the initial spray flow rate is increased to yield a coating density of 75 percent of specification at the second density measurement for subsequent substrate(s) coating. If the density of the coating at the second density measurement is too high, the flow rate for the final 25 percent of the spray regions is decreased to provide for a final density according to specification. Also, the initial flow rate is decreased to yield a coating density of 75 percent of specification at the second density measurement for subsequent substrate(s) coating. Variations of this system may, in some embodiments, further include including moisture detection to monitor drying rates in the drying regions to ensure that the coating is at the specified dryness prior to subsequent sprayings or final drying. Drying rates may, in some embodiments, may be altered by increasing temperature, air flow, or both in the drying regions.

[0071] Images of coated electrodes are depicted in FIGURES 10A through 10C, wherein FIGURE 10A depicts an electrode material loading of 2.5 mg/cm^2 , 10B is loaded at 5.0 mg/cm^2 , and 10C is loaded at 10 mg/cm^2 . The coating is evenly distributed as evidenced by the consistent darkness across each electrode surface.

[0072] FIGURES 11A through 11D depict Scanning Electron Micrograph (SEM) images at 100X, 1,000X, 10,000X, and 100,000X magnification of an anode made using a preferred method of the invention. Of interest is FIGURE 11D where Carbon Nanotubes 1800 can be seen among graphite particles having an average diameter of about $150 \text{ }\mu\text{m}$.

[0073) Turning to FIGURE 12, an exemplary Charge & Discharge Curves are depicted for an anode produced using a preferred embodiment of the invention. The dashed line represents the 1st discharge of the half-cell. The solid line represents the 1st charge of the half-cell. The anode comprised graphite as the active material and carbon nanotubes for conductive particles. The binder Styrene-Butadiene Rubber (SBR) was also included in the coating suspension. According to the graph, the anode had a capacity of about 270mAh/g.

[0074) Anode capacity profiles we conducted on two replicate anodes as depicted in FIGURES 13A and 13B. Here, the half-cell data shows the anodes to be resistant to significant fade over about 100 cycles

[0075) A voltage time curve is presented in FIGURE 14 wherein the graph depicts approximately equal charge and discharge times suggesting that irreversible loss is relatively minimal.

[0076) When compared to a commercially available graphite based anode, an anode produced by the preferred method of the invention yields an electrode with a higher power capacity by a margin of about 2X to 5X over the commercially available anode. FIGURE 15 depicts a Current v. Charge graph wherein the lines represented by the circles and triangles are data derived from an anode produced using the preferred method of the invention. The line represented with squares was derived from a commercially available graphite anode.

[0077) A Capacity v. Current graph for two replicate anodes is depicted in FIGURE 16. Charge over a wide-range of current rates was well maintained.

[0078) A Capacity v. Half-Cycle data is presented in FIGURE 17 for two replicate anodes.

[0079) Images of coated electrodes made using a preferred method of the invention are depicted in FIGURES 18A and 18B, wherein FIGURE 18A depicts an electrode material loading of 2.5 mg/cm², 18B is loaded at 15 mg/cm², and 10B is loaded at 30 mg/cm². The coating is evenly distributed as evidenced by the consistent darkness across each electrode surface.

[0080) A 10,000X SEM of a cathode made using a preferred method of the invention in FIGURE 19. The cathode comprised LiFePO₄, carbon nanotubes, and SBR binder.

[0081) Charge and discharge data for a cathode made using a preferred method of the invention is depicted in FIGURE 20. Of interest is that the time distances between the peak and valley of each cycle are approximately equal indicating good levels of reversible charge capacity. FIGURE 21 represents the same data in a different format to better illustrate the charge time/discharge time differential, again indicating good reversible charge capacity.

[0082) Fade was studied for a cathode made by a preferred method of the invention. Replicate cathodes were tested and the results depicted in FIGURES 22A and 22B, the latter showing minimal fade over 80 cycles.

[0083) FIGURES 23 and 24 depict power curves for sample electrodes produced using a preferred method of the invention, the latter figure showing a commercially available electrode for comparison.

[0084) While the present invention has been described with reference to specific embodiments, it should be understood by those skilled in the art that obvious changes may be made and equivalents may be substituted without departing from the true spirit and scope of the invention. In addition, many modifications may be made to adapt the methods and devices of the present invention to particular situations, materials, compositions of matter, processes, process step or steps, to the objective, spirit and scope of the present invention. All such modifications are intended to be within the scope of the claims appended hereto.

EXAMPLES

Example 1 - Basic Spray/Dry Process

[0085) Basic spray/dry method was tested using an airbrush filled with a suspension containing:

[0086) Spraying was performed manually with a back and forth motion of the spray head parallel to the surface of the substrate. Approximately 40 passes were made to load the surface to a desired amount.

Example 2 – Multi-step Spray/Dry Process

[0087)

Example 3 - Fabrication of Electrodes into a Cell

[0088) Circles were cut from each type of electrode (cathode/anode) in a size to fit into a pouch. A porous polymer sheet was placed between the electrodes as they were layered into the pouch. Electrolyte (LiPF_6) was added prior to vacuum sealing the pouch to form a pouch cell.

Example 4 - Testing of Cell

[0089) The following protocol was followed to test cells made with the electrodes of the invention:

- a) Measure open circuit voltage (OCV) (10 sec)
- b) Apply 1sec current pulse (0.5 mA for coin cells, 5-10 mA for pouch cells)
- c) Measure voltage drop between OCV and the first 10 msec of applied pulse
- d) Impedance testing: A few special cells, especially large pouch cells:
- e) Measure impedance from 1000 kHz to 0.01 Hz

[0090) Anode half-cells

- a) Resistance test
- b) Initial capacity test in constant current mode (3 cycles, starting with discharge cycle, each cycle running at 25 mA/g and then lowering to 12.5 mA/g until voltage limit is reached - designated "25 + 12.5 mA/g")
 - (a) For graphite $\frac{1}{2}$ -cells, voltage limits are 0.01V and 1.5V
 - (b) For silicon $\frac{1}{2}$ -cells, voltage limits 0.07V to 1.0V
- c) Resistance test
 - i) Power test* up to 10 mA total current
 - ii) followed by power test up to 20 mA, if charge withdrawn at 10 mA step is $\geq 70\%$ total capacity
 - iii) followed by power test up to 30 mA, if charge withdrawn at 10 mA step is $\geq 80\%$ total capacity
- d) fade testing: capacity test in constant current mode (100 cycles at "25 + 12.5 mA/g", with a resistance and a power test every 25 cycles)

[0091) *Power test:

- a) - discharge down to lower voltage limit at "25 + 12.5" mA/g
- b) - charge at highest current until upper voltage limit
- c) - rest 5 minutes
- d) - charge at half the previous current
- e) - rest 5 minutes
- f) - etc., until the current is at or below 25 mA/g

[0092) Cathode half-cells

- a) Resistance test
- b) Initial capacity test in constant current mode (3 cycles, starting with charge cycle, each cycle running at 12.5 mA/g and then lowering to 6.25 mA/g until voltage limit is reached - designated "12.5 + 6.25 mA/g")

- i) For LiFePO₄ ½-cells, voltage limits are 4.1V and 2.0V
- ii) For other cathode chemistries, voltage limits may be a few 0.1's of volts higher
- c) Resistance test
- d) Power test* up to 10 mA total current
 - i) - followed by power test up to 20 mA, if charge withdrawn at 10 mA step is $\geq 70\%$ total capacity
 - ii) - followed by power test up to 30 mA, if charge withdrawn at 10 mA step is $\geq 80\%$ total capacity
- e) Fade testing: capacity test in constant current mode (100 cycles at “12.5 + 6.25 mA/g”, with a resistance and a power test every 25 cycles)

[0093) *Power test:

- a) - charge up to upper voltage limit at “12.5 + 6.25 mA/g”
- b) - discharge at highest current until lower voltage limit
- c) - rest 5 minutes
- d) - discharge at half the previous current
- e) - rest 5 minutes
- f) - etc., until the current is at or below 12.5 mA/g

[0094) Full cells (matched)

- a) Resistance test
- b) Initial capacity test in constant current mode (3 cycles, starting with discharge cycle, each cycle running at either “25 + 12.5 mA/g” (anode weight) or “12.5 + 6.25 mA/g” (cathode weight), whichever is smaller)
 - i) For graphite anode and LiFePO₄ cathode full cells, voltage limits are 2.0 and 4.1V

- ii) For cells with other cathodes, voltage limits may be a few 0.1V higher
 - c) Resistance test
 - d) Power test* up to 10 mA total current
 - i) - followed by power test up to 20 mA, if charge withdrawn at 10 mA step is $\geq 70\%$ total capacity
 - ii) - followed by power test up to 30 mA, if charge withdrawn at 10 mA step is $\geq 80\%$ total capacity
 - e) Fade testing: capacity test in constant current mode (100 cycles at “25 + 12.5 mA/g” (anode) or “12.5 + 6.25 mA/g” (cathode), whichever is smaller, with a resistance and a power test every 25 cycles)
- [0095) Test equipment
- [0096) For resistance and impedance tests: potentiostat/galvanostat
- a) • Princeton Applied Research: Versastat V3
- [0097) For capacity and power: battery testers:
- a) • Manufacturer: Neware Technology Limited
 - b) • Models (for different current ranges):
 - i) BTS-5V10A(8CH) 10 mA limit
 - ii) BTS-5V100A(8CH) 100 mA limit
 - iii) BTS-5V200A(8CH) 200 mA limit

We claim:

1. A method for coating a substrate comprising the steps of:
 - a) providing a substrate having a surface;
 - b) providing an active material suspension comprising:
 - i) active material particles, said active material particles capable of reversibly storing ions; and,
 - ii) electrically conductive particles; and,
 - iii) a solvent;
 - c) spraying said active material suspension onto said substrate surface to form a first coating layer;
 - d) evaporating a portion of said solvent, if any, from said first coating layer; and,
 - e) repeating said steps (c) through step (e) for at least two repetitions.
2. The method of claim 1 wherein said steps (c) and (d) are repeated at least five times.
3. The method of claim 1 wherein said steps (c) and (d) are repeated at least ten times.
4. The method of claim 1 wherein said steps (c) and (d) are repeated at least twenty times.
5. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 10% w/w prior to repeating said spraying step.

6. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 20% w/w prior to repeating said spraying step.
7. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 30% w/w prior to repeating said spraying step.
8. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 40% w/w prior to repeating said spraying step.
9. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 50% w/w prior to repeating said spraying step.
10. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 60% w/w prior to repeating said spraying step.
11. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 70% w/w prior to repeating said spraying step.
12. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 80% w/w prior to repeating said spraying step.
13. The method of claim 1 wherein said solvent in said coating layer is at a content level of less than 90% w/w prior to repeating said spraying step.

14. The method of claim 1 wherein said active material suspension is sprayed using an aerosol sprayer.

15. The method of claim 1 wherein said active material suspension is sprayed using an airless sprayer.

16. The method of claim 1 wherein said active material suspension is sprayed using an ultrasonic sprayer.

17. The method of claim 1 wherein said active material suspension is sprayed using a pulse width modulated sprayer.

18. The method of claim 1 wherein said active material suspension is sprayed using electro-spray deposition.

19. The method of claim 1 wherein said active material suspension is sprayed in a volumetrically controlled manner.

20. The method of claim 1 wherein said evaporating step further comprises detecting the amount of solvent in said coating layer.

21. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 20% w/w prior to repeating said spraying step.
22. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 30% w/w prior to repeating said spraying step.
23. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 40% w/w prior to repeating said spraying step.
24. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 50% w/w prior to repeating said spraying step.
25. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 60% w/w prior to repeating said spraying step.
26. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 70% w/w prior to repeating said spraying step.
27. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 80% w/w prior to repeating said spraying step.
28. The method of claim 20 wherein said solvent in said coating layer is at a content level of less than 90% w/w prior to repeating said spraying step.

29. The method of claim 1 wherein the thickness of said coating layer is measured prior to said repeating of said spraying and evaporating steps.
30. The method of claim 1 wherein the density of said coating layer is measured prior to said repeating of said spraying and evaporating steps.
31. The method of claim 1 wherein said solvent is a non-organic solvent.
32. The method of claim 31 wherein said non-organic solvent is water.
33. The method of claim 1 wherein said solvent is an organic solvent.
34. The method of claim 33 wherein said organic solvent is selected from the group consisting of: alcohol; methanol; ethanol; propanol; isopropanol; butanol; tert-butanol; pentanol; hexanol; methane; ethane; propane; butane; pentane; hexane; heptane; octane; acetone; and, N-methylpyrrolidone.
35. The method of claim 1 wherein said solvent comprises a mixture of alcohol and water.
36. The method of claim 1 wherein said solvent comprises ethanol.

37. The method of claim 1 wherein said solvent comprises acetone.
38. The method of claim 1 wherein said solvent comprises N-methylpyrrolidone.
39. The method of claim 1 wherein said spraying step is operationally linked to a detector monitoring at least one attribute of the coating layer so that the spray volume is adapted in real-time in response to control, wholly or partly, a degree of said attribute.
40. The method of claim 1 wherein said substrate is wound about an axis to form a substrate roll and said substrate is unwound from the roll and is traversed through a spraying region wherein said first spraying step occurs.
41. The method of claim 40 wherein after the substrate traverses through said spraying region, said substrate is then traversed through a evaporating region where said first evaporating step occurs.
42. The method of claim 41 wherein said substrate subsequently traverses through a second spraying region then a second evaporating region and so forth until a desired number of coating layers are built upon said substrate surface.
43. The method of claim 1 wherein said substrate further comprises a second surface on a side of said substrate opposite said first substrate surface.

44. The method of claim 43 wherein said spraying step and said evaporating step are applied simultaneously to said first and said second substrate surfaces to form a first coating layer upon said substrate first surface and a second coating layer upon said substrate second surface to yield a double-sided coating on said substrate surfaces.

45. The method of claim 43 wherein said spraying step and said evaporating step are applied alternately to said first and said second substrate surfaces to form a first coating layer upon said substrate first surface and a second coating layer upon said substrate second surface to yield a double-sided coating on said substrate surfaces.

46. The method of claim 1 wherein a subsequent coating layer comprises materials different from said active material particles and said electrically conductive particles.

47. The method of claim 1 wherein said evaporating step further comprises providing a heat source.

48. The method of claim 47 wherein said heat source comprises an infrared heating element.

49. The method of claim 47 wherein said heat source comprises a gas-catalytic heat source.

50. The method of claim 47 wherein said heat source comprises a radio frequency transmitter.
51. The method of claim 47 wherein said heat source comprises a convective heat element.
52. The method of claim 1 wherein said evaporating step further comprises providing an air flow apparatus for passing air across said surface of said substrate during said evaporating step.
53. The method of claim 52 wherein said air passing across said surface of said substrate surface is heated.
54. The method of claim 52 wherein said air passing across said surface of said substrate is not heated.
55. The method of claim 52 wherein said air passing across said surface of said substrate is cooled.
56. The method of claim 52 further comprising two or more air flow apparatuses wherein at least one air flow apparatus passed heated air across a portion of said surface of said substrate at one point in time and then passes cooled air across said portion of said surface of said substrate at another point in time.

57. The method of claim 1 wherein said solvent is a mixed solvent comprising at least two different solvents.
58. The method of claim 1 wherein said solvent is selected from the group consisting of: polar solvents; polar aprotic solvents; and, non-polar solvents.
59. The method of claim 1 wherein said solvent is selected from the group consisting of: water; methanol; ethanol; propanol; isopropanol; butanol; tert-butanol; pentane; hexane; heptane; acetone; dimethylformamide; n-methyl-2-pyrrolidone; and, 1,3-dimethyl-2-imidazolidinone.
60. The method of claim 1 wherein said substrate comprises a metal.
61. The method of claim 1 wherein said substrate comprises aluminum.
62. The method of claim 1 wherein said substrate comprises copper.
63. The method of claim 1 wherein said substrate comprises nickel.
64. The method of claim 1 wherein said substrate comprises a non-metal.
65. The method of claim 1 wherein said substrate comprises a polymer.

66. The method of claim 65 wherein said substrate comprises a polymer selected from the group consisting of: acrylonitrile butadiene styrene (ABS); allylmethacrylate; polyacrylonitrile (PAN); acrylic; polyamide; polyaramides; polyacrylamide; polyvinylcaprolactam; polypropylene oxide (PPO); polystyrene (PS); polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE); polyvinylidene fluoride – tetrafluoroethylene (PVDF-TFE); polybutadiene; poly(butylene terephthalate) (PBT); polycarbonate; polychloroprene; poly(cis-1,4-isoprene); polyester; poly(ether sulfone) (PES, PES/PEES); poly(ether-ether ketone)s (PEEK, PES/PEEK); polyethylene (PE); poly(ethylene glycol) (PEG); poly(ethylene terephthalate) (PET); polyethylene oxide (PEO); poly(2-hydroxymethylmethacrylate); polypropylene (PP); poly(trans-1,4-isoprene); poly (methyl acrylate); poly (methyl methacrylate); polytetrafluoroethylene (PTFE); poly(trimethylene terephthalate) (PTT); polyurethane (PU); polyvinyl butyral (PVB); polyvinylchloride (PVC); polyvinylidenedifluoride (PVDF); poly(vinyl pyrrolidone) (PVP); nylon; silicone rubbers; sodium polyacrylate; styrene-acrylonitrile resin (SAN); polymeric organosilicon; polydimethylsiloxane; and, ethylene glycol dimethacrylate.

67. The method of claim 65 wherein said polymer is polypropylene and said support is a porous film comprising polypropylene.

68. The method of claim 65 wherein said support comprises three layers, each layer comprising a polymer material.

69. The method of claim 68 wherein said three layers comprises a porous polyethylene sheet sandwiched between two porous polypropylene sheets.
70. The method of claim 65 wherein said support is an ion permeable electrically non-conductive battery separator.
71. The method of claim 1 wherein said substrate comprises a non-woven material.
72. The method of claim 1 wherein said substrate comprises a woven material.
73. The method of claim 1 wherein said substrate comprises pores.
74. The method of claim 1 wherein said substrate is a foil.
75. The method of claim 1 wherein said substrate is a film.
76. The method of claim 1 wherein said substrate comprises a plurality of layers.
77. The method of claim 76 wherein two or more of said plurality of layers are different.
78. The method of claim 76 wherein two or more of said plurality of layers are the same.

79. The method of claim 1 wherein said active material particles comprise an anode active material capable of reversibly storing an ion.
80. The method of claim 1 wherein said active material particles further comprise lithium ions stored therein.
81. The method of claim 1 wherein said active material particles comprise a cathode active material capable of reversibly storing an ion.
82. The method of claim 1 wherein said active material comprises a cathode active material selected from the group consisting of: LiFePO_4 ; LiCoO_2 ; LiMnO_2 ; LiMn_2O_4 ; $\text{LiMn}_{1/2}\text{Ni}_{1/2}\text{O}_2$; $\text{LiFe}(\text{Zr})\text{PO}_4$; and, $\text{Li}(\text{Ni}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3})\text{O}_2$.
83. The method of claim 1 wherein said active material particles comprise a material selected from the list consisting of: Li_3BiF_3 ; $\text{Li}_3\text{Bi}_2\text{O}_3$; LiCoO_2 ; Li_2CoF_2 ; Li_3CrF_3 ; $\text{Li}_3\text{Cr}_2\text{O}_3$; Li_2CuF_2 ; Li_2CuO ; Li_2CuS ; Li_3FeF_3 ; $\text{Li}_3\text{Fe}_2\text{O}_3$; Li_2FeF_2 ; Li_2FeO ; Li_2FeS ; Li_2MnF_2 ; Li_2MnO ; LiMn_2O_4 ; Li_3MnF_3 ; $\text{Li}_3\text{Mn}_2\text{O}_3$; Li_2MnS ; Li_2NiF_2 ; LiNiO_2 ; Li_2NiO ; Li_3VF_3 ; and, $\text{Li}_3\text{V}_2\text{O}_3$.
84. The method of claim 1 wherein said active material particles comprise an oxide of a metal selected from the group consisting of: aluminum; chromium; cobalt; iron; nickel; magnesium; manganese; molybdenum; titanium; and, vanadium.

85. The method of claim 1 wherein said active material particles comprise a lithium-transition metal-phosphate compound doped with a material selected from the group consisting of: metals, metalloids, and, halogens.
86. The method of claim 1 wherein said active material particles comprise an olivine structure LiMPO_4 compound, where M is selected from the group of metals consisting of: vanadium, chromium, manganese, iron, cobalt, and nickel.
87. The method of claim 1 wherein said active material particles comprise an olivine structure LiMPO_4 compound having lithium sites with deficiencies, said deficiencies being compensated by the addition of a metal or metalloid.
88. The method of claim 1 wherein said active material particles comprise an olivine structure LiMPO_4 having metal sites, wherein at least a portion of said metal sites are doped.
89. The method of claim 1 wherein said active material particles comprise an olivine structure LiMPO_4 compound having oxygen sites, said oxygen sites having deficiencies compensated by the addition of a halogen.
90. The method of claim 1 wherein said active material particles comprises $\text{Li}_x\text{NyM}_{1-y}\text{O}_2$, wherein M comprises a metal selected from the group consisting of: a transitional metal; titanium; vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc; and aluminum, and, $0.05 \leq x \leq 1.10$ and $0.5 \leq y \leq 1.0$).

91. The method of claim 1 wherein said active material particles comprise a titanium containing compound selected from the group consisting of: Li_2TiO_3 ; $\text{Li}_4\text{Ti}_5\text{O}_{12}$; $\text{Li}_7\text{Ti}_5\text{O}_{12}$; $\text{Li}_4\text{Ti}_{5-x}\text{M}_x\text{O}_{12}$; $\text{Li}_4\text{Ti}_5\text{-ZM}^1_{z1}\text{M}^2_{z2}\text{M}^3_{z3} \dots \text{M}^k_{zk}\text{O}_{12}$; $\text{Li}_4\text{Ti}_{5-x-b}\text{M}_x\text{B}_b\text{O}_{12}$; $\text{Li}_{3+a}\text{Ti}_{6-a-x}\text{M}_x\text{O}_{12}$; $\text{Li}_{3+a}\text{Ti}_{6-a-x-b}\text{M}_x\text{B}_b\text{O}_{12}$, and $\text{Li}_{4-c}\text{Mg}_c\text{Ti}_{5-x}\text{M}_x\text{O}_{12}$, wherein Z has a value from about 0.1 to about 2.5; $z_1, z_2, z_3, \dots, z_k$ independently have a value from about 0 to about 2.5; Z and $z_1, z_2, z_3, \dots, z_k$ satisfy the equation: $Z=z_1+z_2+z_3+\dots+zk$; x has a value from about 0.1 to about 2.5, a has a value from about 0 to about 1, b has a value from about 0 to about 2.5, and c has a value from about 0 to about 1.5; M is one or more cations selected from the group of V, Cr, Nb, Mo, Ta, and W; $M_1, M_2, M_3, \dots, M_k$ are cations independently selected from the group of V, Cr, Nb, Mo, Ta, and W; and B is one or more cations selected from the group of Zr, Ce, Si, and Ge.

92. The method of claim 1 wherein said active material particles comprise a poor metal selected from the group consisting of: aluminium; antimony; bismuth; gallium; germanium; indium; lead; polonium; thallium; and, tin.

93. The method of claim 1 wherein said active material particles comprise a pnictogen selected from the group consisting of: nitrogen; phosphorus; arsenic; antimony; and, bismuth.

94. The method of claim 1 wherein said active material particles comprise lithium metal.

95. The method of claim 94 wherein said active material particles further comprise a non-lithium metal selected from the group of metals consisting of: aluminum; chromium; cobalt; iron; nickel; magnesium; manganese; molybdenum; titanium; and, vanadium.

96. The method of claim 1 wherein the active material particles comprise an olivine lithium metal phosphate material having the formula $\text{Li}_x\text{M}'_y\text{M}''_z\text{PO}_4$,

wherein M' comprises a metal selected from the group consisting of:
manganese and iron,

wherein M'' comprises a metal selected from the group consisting of:
manganese; cobalt; and, nickel,

wherein M' is not the same as M'' , and,

wherein x is greater than or equal to 0, and x is less than or equal to 1.2; y is greater than or equal to 0.7, and y is less than or equal to 0.95; z is greater than or equal to 0.02, and z is greater than or equal to 0.3; and, the sum of y and z is greater than or equal to 0.8, and the sum of y and z is less than or equal to 1.2.

97. The method of claim 96, wherein z is greater than or equal to 0.02, and z is less than or equal to 0.1.

98. The method of claim 96, wherein the sum of y and z equals 1.

99. The method of claim 96, wherein M' is iron, and z is greater than or equal to 0.02, and z is less than or equal to 0.1.

100. The method of claim 96, wherein the sum of y and z equals 1.
101. The method of claim 96, wherein the sum of y and z is greater than or equal to 0.8, and the sum of y and z is less than or equal to 1.
102. The method of claim 1 wherein the active material particles comprise a lithium transition metal phosphate material having an overall composition of $\text{Li}_{1-x}\text{MPO}_4$, wherein M comprises at least one first row transition metal selected from the group consisting of titanium, vanadium, chromium, manganese, iron, cobalt and nickel, and wherein in use x ranges from 0 to 1.
103. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0.1 to about 0.3.
104. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.15 at room temperature.
105. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to at least about 0.07 at room temperature.
106. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.05 at room temperature.

107. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.8.

108. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.9.

109. The method of claim 102 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.95.

110. The method of claim 1 wherein said active material comprises a material having the formula $\text{Li}_{1-x}\text{M}_x\text{FePO}_4$,

wherein M is a dopant selected from the group consisting of: titanium;

vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc;

zirconium; niobium; molybdenum; silver; and, tungsten, and,

wherein x is a number selected from the group consisting of: about 0.00; about 0.01; about 0.02; about 0.03; about 0.04; about 0.05; about 0.06; about 0.07; about 0.08; about 0.09; about 0.10; about 0.11; about 0.12; about 0.13; about 0.14; about 0.15; about 0.16; about 0.17; about 0.18; about 0.19; about 0.20; about 0.21; about 0.22; about 0.23; about 0.24; about 0.25; about 0.26; about 0.27; about 0.28; about 0.29; about 0.30; about 0.31; about 0.32; about 0.33; about 0.34; about 0.35; about 0.36; about 0.37; about 0.38; about 0.39; about 0.40; about 0.41; about 0.42; about 0.43; about 0.44; about 0.45; about 0.46; about 0.47; about 0.48; about 0.49; about 0.50; about 0.51; about 0.52; about 0.53; about 0.54; about 0.55; about 0.56; about 0.57; about 0.58; about 0.59;

about 0.60; about 0.61; about 0.62; about 0.63; about 0.64; about 0.65; about 0.66; about 0.67; about 0.68; about 0.69; about 0.70; about 0.71; about 0.72; about 0.73; about 0.74; about 0.75; about 0.76; about 0.77; about 0.78; about 0.79; about 0.80; about 0.81; about 0.82; about 0.83; about 0.84; about 0.85; about 0.86; about 0.87; about 0.88; about 0.89; about 0.90; about 0.91; about 0.92; about 0.93; about 0.94; about 0.95; about 0.96; about 0.97; about 0.98; about 0.99; and, about 1.00.

111. The method of claim 1 wherein the active material comprises a material having the formula $\text{Li}_{1-x}\text{M}_x\text{FePO}_4$,

wherein M is a metal selected from the group consisting of: titanium;

vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc;

zirconium; niobium; molybdenum; silver; and, tungsten, and,

wherein x is a number range selected from the group consisting of: from about 0.00 to about 0.01; from about 0.00 to about 0.02; from about 0.00 to about 0.03; from about 0.00 to about 0.04; from about 0.00 to about 0.05; from about 0.00 to about 0.06; from about 0.00 to about 0.07; from about 0.00 to about 0.08; from about 0.00 to about 0.09; from about 0.00 to about 0.10; from about 0.00 to about 0.11; from about 0.00 to about 0.12; from about 0.00 to about 0.13; from about 0.00 to about 0.14; from about 0.00 to about 0.15; from about 0.00 to about 0.16; from about 0.00 to about 0.17; from about 0.00 to about 0.18; from about 0.00 to about 0.19; from about 0.00 to about 0.20; from about 0.00 to about 0.21; from about 0.00 to about 0.22; from about 0.00 to about

0.23; from about 0.00 to about 0.24; from about 0.00 to about 0.25; from about 0.00 to about 0.26; from about 0.00 to about 0.27; from about 0.00 to about 0.28; from about 0.00 to about 0.29; from about 0.00 to about 0.30; from about 0.00 to about 0.31; from about 0.00 to about 0.32; from about 0.00 to about 0.33; from about 0.00 to about 0.34; from about 0.00 to about 0.35; from about 0.00 to about 0.36; from about 0.00 to about 0.37; from about 0.00 to about 0.38; from about 0.00 to about 0.39; from about 0.00 to about 0.40; from about 0.00 to about 0.41; from about 0.00 to about 0.42; from about 0.00 to about 0.43; from about 0.00 to about 0.44; from about 0.00 to about 0.45; from about 0.00 to about 0.46; from about 0.00 to about 0.47; from about 0.00 to about 0.48; from about 0.00 to about 0.49; from about 0.00 to about 0.50; from about 0.00 to about 0.51; from about 0.00 to about 0.52; from about 0.00 to about 0.53; from about 0.00 to about 0.54; from about 0.00 to about 0.55; from about 0.00 to about 0.56; from about 0.00 to about 0.57; from about 0.00 to about 0.58; from about 0.00 to about 0.59; from about 0.00 to about 0.60; from about 0.00 to about 0.61; from about 0.00 to about 0.62; from about 0.00 to about 0.63; from about 0.00 to about 0.64; from about 0.00 to about 0.65; from about 0.00 to about 0.66; from about 0.00 to about 0.67; from about 0.00 to about 0.68; from about 0.00 to about 0.69; from about 0.00 to about 0.70; from about 0.00 to about 0.71; from about 0.00 to about 0.72; from about 0.00 to about 0.73; from about 0.00 to about 0.74; from about 0.00 to about 0.75; from about 0.00 to about 0.76; from about 0.00 to about 0.77; from about 0.00 to about 0.78; from about 0.00 to about 0.79; from about 0.00 to about 0.80; from about

0.00 to about 0.81; from about 0.00 to about 0.82; from about 0.00 to about 0.83; from about 0.00 to about 0.84; from about 0.00 to about 0.85; from about 0.00 to about 0.86; from about 0.00 to about 0.87; from about 0.00 to about 0.88; from about 0.00 to about 0.89; from about 0.00 to about 0.90; from about 0.00 to about 0.91; from about 0.00 to about 0.92; from about 0.00 to about 0.93; from about 0.00 to about 0.94; from about 0.00 to about 0.95; from about 0.00 to about 0.96; from about 0.00 to about 0.97; from about 0.00 to about 0.98; from about 0.00 to about 0.99; from about 0.00 to about 0.10; from about 0.10 to about 0.11; from about 0.10 to about 0.12; from about 0.10 to about 0.13; from about 0.10 to about 0.14; from about 0.10 to about 0.15; from about 0.10 to about 0.16; from about 0.10 to about 0.17; from about 0.10 to about 0.18; from about 0.10 to about 0.19; from about 0.10 to about 0.20; from about 0.10 to about 0.21; from about 0.10 to about 0.22; from about 0.10 to about 0.23; from about 0.10 to about 0.24; from about 0.10 to about 0.25; from about 0.10 to about 0.26; from about 0.10 to about 0.27; from about 0.10 to about 0.28; from about 0.10 to about 0.29; from about 0.10 to about 0.30; from about 0.10 to about 0.31; from about 0.10 to about 0.32; from about 0.10 to about 0.33; from about 0.10 to about 0.34; from about 0.10 to about 0.35; from about 0.10 to about 0.36; from about 0.10 to about 0.37; from about 0.10 to about 0.38; from about 0.10 to about 0.39; from about 0.10 to about 0.40; from about 0.10 to about 0.41; from about 0.10 to about 0.42; from about 0.10 to about 0.43; from about 0.10 to about 0.44; from about 0.10 to about 0.45; from about 0.10 to about 0.46; from about 0.10 to about 0.47; from about 0.10 to about

0.48; from about 0.10 to about 0.49; from about 0.10 to about 0.50; from about 0.10 to about 0.51; from about 0.10 to about 0.52; from about 0.10 to about 0.53; from about 0.10 to about 0.54; from about 0.10 to about 0.55; from about 0.10 to about 0.56; from about 0.10 to about 0.57; from about 0.10 to about 0.58; from about 0.10 to about 0.59; from about 0.10 to about 0.60; from about 0.10 to about 0.61; from about 0.10 to about 0.62; from about 0.10 to about 0.63; from about 0.10 to about 0.64; from about 0.10 to about 0.65; from about 0.10 to about 0.66; from about 0.10 to about 0.67; from about 0.10 to about 0.68; from about 0.10 to about 0.69; from about 0.10 to about 0.70; from about 0.10 to about 0.71; from about 0.10 to about 0.72; from about 0.10 to about 0.73; from about 0.10 to about 0.74; from about 0.10 to about 0.75; from about 0.10 to about 0.76; from about 0.10 to about 0.77; from about 0.10 to about 0.78; from about 0.10 to about 0.79; from about 0.10 to about 0.80; from about 0.10 to about 0.81; from about 0.10 to about 0.82; from about 0.10 to about 0.83; from about 0.10 to about 0.84; from about 0.10 to about 0.85; from about 0.10 to about 0.86; from about 0.10 to about 0.87; from about 0.10 to about 0.88; from about 0.10 to about 0.89; from about 0.10 to about 0.90; from about 0.10 to about 0.91; from about 0.10 to about 0.92; from about 0.10 to about 0.93; from about 0.10 to about 0.94; from about 0.10 to about 0.95; from about 0.10 to about 0.96; from about 0.10 to about 0.97; from about 0.10 to about 0.98; from about 0.10 to about 0.99; from about 0.10 to about 1.00; from about 0.20 to about 0.21; from about 0.20 to about 0.22; from about 0.20 to about 0.23; from about 0.20 to about 0.24; from about 0.20 to about 0.25; from about

0.20 to about 0.26; from about 0.20 to about 0.27; from about 0.20 to about 0.28; from about 0.20 to about 0.29; from about 0.20 to about 0.30; from about 0.20 to about 0.31; from about 0.20 to about 0.32; from about 0.20 to about 0.33; from about 0.20 to about 0.34; from about 0.20 to about 0.35; from about 0.20 to about 0.36; from about 0.20 to about 0.37; from about 0.20 to about 0.38; from about 0.20 to about 0.39; from about 0.20 to about 0.40; from about 0.20 to about 0.41; from about 0.20 to about 0.42; from about 0.20 to about 0.43; from about 0.20 to about 0.44; from about 0.20 to about 0.45; from about 0.20 to about 0.46; from about 0.20 to about 0.47; from about 0.20 to about 0.48; from about 0.20 to about 0.49; from about 0.20 to about 0.50; from about 0.20 to about 0.51; from about 0.20 to about 0.52; from about 0.20 to about 0.53; from about 0.20 to about 0.54; from about 0.20 to about 0.55; from about 0.20 to about 0.56; from about 0.20 to about 0.57; from about 0.20 to about 0.58; from about 0.20 to about 0.59; from about 0.20 to about 0.60; from about 0.20 to about 0.61; from about 0.20 to about 0.62; from about 0.20 to about 0.63; from about 0.20 to about 0.64; from about 0.20 to about 0.65; from about 0.20 to about 0.66; from about 0.20 to about 0.67; from about 0.20 to about 0.68; from about 0.20 to about 0.69; from about 0.20 to about 0.70; from about 0.20 to about 0.71; from about 0.20 to about 0.72; from about 0.20 to about 0.73; from about 0.20 to about 0.74; from about 0.20 to about 0.75; from about 0.20 to about 0.76; from about 0.20 to about 0.77; from about 0.20 to about 0.78; from about 0.20 to about 0.79; from about 0.20 to about 0.80; from about 0.20 to about 0.81; from about 0.20 to about 0.82; from about 0.20 to about

0.83; from about 0.20 to about 0.84; from about 0.20 to about 0.85; from about 0.20 to about 0.86; from about 0.20 to about 0.87; from about 0.20 to about 0.88; from about 0.20 to about 0.89; from about 0.20 to about 0.90; from about 0.20 to about 0.91; from about 0.20 to about 0.92; from about 0.20 to about 0.93; from about 0.20 to about 0.94; from about 0.20 to about 0.95; from about 0.20 to about 0.96; from about 0.20 to about 0.97; from about 0.20 to about 0.98; from about 0.20 to about 0.99; from about 0.20 to about 1.00; from about 0.30 to about 0.31; from about 0.30 to about 0.32; from about 0.30 to about 0.33; from about 0.30 to about 0.34; from about 0.30 to about 0.35; from about 0.30 to about 0.36; from about 0.30 to about 0.37; from about 0.30 to about 0.38; from about 0.30 to about 0.39; from about 0.30 to about 0.40; from about 0.30 to about 0.41; from about 0.30 to about 0.42; from about 0.30 to about 0.43; from about 0.30 to about 0.44; from about 0.30 to about 0.45; from about 0.30 to about 0.46; from about 0.30 to about 0.47; from about 0.30 to about 0.48; from about 0.30 to about 0.49; from about 0.30 to about 0.50; from about 0.30 to about 0.51; from about 0.30 to about 0.52; from about 0.30 to about 0.53; from about 0.30 to about 0.54; from about 0.30 to about 0.55; from about 0.30 to about 0.56; from about 0.30 to about 0.57; from about 0.30 to about 0.58; from about 0.30 to about 0.59; from about 0.30 to about 0.60; from about 0.30 to about 0.61; from about 0.30 to about 0.62; from about 0.30 to about 0.63; from about 0.30 to about 0.64; from about 0.30 to about 0.65; from about 0.30 to about 0.66; from about 0.30 to about 0.67; from about 0.30 to about 0.68; from about 0.30 to about 0.69; from about 0.30 to about 0.70; from about

0.30 to about 0.71; from about 0.30 to about 0.72; from about 0.30 to about 0.73; from about 0.30 to about 0.74; from about 0.30 to about 0.75; from about 0.30 to about 0.76; from about 0.30 to about 0.77; from about 0.30 to about 0.78; from about 0.30 to about 0.79; from about 0.30 to about 0.80; from about 0.30 to about 0.81; from about 0.30 to about 0.82; from about 0.30 to about 0.83; from about 0.30 to about 0.84; from about 0.30 to about 0.85; from about 0.30 to about 0.86; from about 0.30 to about 0.87; from about 0.30 to about 0.88; from about 0.30 to about 0.89; from about 0.30 to about 0.90; from about 0.30 to about 0.91; from about 0.30 to about 0.92; from about 0.30 to about 0.93; from about 0.30 to about 0.94; from about 0.30 to about 0.95; from about 0.30 to about 0.96; from about 0.30 to about 0.97; from about 0.30 to about 0.98; from about 0.30 to about 0.99; from about 0.30 to about 1.00; from about 0.40 to about 0.40; from about 0.40 to about 0.41; from about 0.40 to about 0.42; from about 0.40 to about 0.43; from about 0.40 to about 0.44; from about 0.40 to about 0.45; from about 0.40 to about 0.46; from about 0.40 to about 0.47; from about 0.40 to about 0.48; from about 0.40 to about 0.49; from about 0.40 to about 0.50; from about 0.40 to about 0.51; from about 0.40 to about 0.52; from about 0.40 to about 0.53; from about 0.40 to about 0.54; from about 0.40 to about 0.55; from about 0.40 to about 0.56; from about 0.40 to about 0.57; from about 0.40 to about 0.58; from about 0.40 to about 0.59; from about 0.40 to about 0.60; from about 0.40 to about 0.61; from about 0.40 to about 0.62; from about 0.40 to about 0.63; from about 0.40 to about 0.64; from about 0.40 to about 0.65; from about 0.40 to about 0.66; from about 0.40 to about

0.67; from about 0.40 to about 0.68; from about 0.40 to about 0.69; from about 0.40 to about 0.70; from about 0.40 to about 0.71; from about 0.40 to about 0.72; from about 0.40 to about 0.73; from about 0.40 to about 0.74; from about 0.40 to about 0.75; from about 0.40 to about 0.76; from about 0.40 to about 0.77; from about 0.40 to about 0.78; from about 0.40 to about 0.79; from about 0.40 to about 0.80; from about 0.40 to about 0.81; from about 0.40 to about 0.82; from about 0.40 to about 0.83; from about 0.40 to about 0.84; from about 0.40 to about 0.85; from about 0.40 to about 0.86; from about 0.40 to about 0.87; from about 0.40 to about 0.88; from about 0.40 to about 0.89; from about 0.40 to about 0.90; from about 0.40 to about 0.91; from about 0.40 to about 0.92; from about 0.40 to about 0.93; from about 0.40 to about 0.94; from about 0.40 to about 0.95; from about 0.40 to about 0.96; from about 0.40 to about 0.97; from about 0.40 to about 0.98; from about 0.40 to about 0.99; from about 0.40 to about 1.00; from about 0.50 to about 0.51; from about 0.50 to about 0.52; from about 0.50 to about 0.53; from about 0.50 to about 0.54; from about 0.50 to about 0.55; from about 0.50 to about 0.56; from about 0.50 to about 0.57; from about 0.50 to about 0.58; from about 0.50 to about 0.59; from about 0.50 to about 0.60; from about 0.50 to about 0.61; from about 0.50 to about 0.62; from about 0.50 to about 0.63; from about 0.50 to about 0.64; from about 0.50 to about 0.65; from about 0.50 to about 0.66; from about 0.50 to about 0.67; from about 0.50 to about 0.68; from about 0.50 to about 0.69; from about 0.50 to about 0.70; from about 0.50 to about 0.71; from about 0.50 to about 0.72; from about 0.50 to about 0.73; from about 0.50 to about 0.74; from about

0.50 to about 0.75; from about 0.50 to about 0.76; from about 0.50 to about 0.77; from about 0.50 to about 0.78; from about 0.50 to about 0.79; from about 0.50 to about 0.80; from about 0.50 to about 0.81; from about 0.50 to about 0.82; from about 0.50 to about 0.83; from about 0.50 to about 0.84; from about 0.50 to about 0.85; from about 0.50 to about 0.86; from about 0.50 to about 0.87; from about 0.50 to about 0.88; from about 0.50 to about 0.89; from about 0.50 to about 0.90; from about 0.50 to about 0.91; from about 0.50 to about 0.92; from about 0.50 to about 0.93; from about 0.50 to about 0.94; from about 0.50 to about 0.95; from about 0.50 to about 0.96; from about 0.50 to about 0.97; from about 0.50 to about 0.98; from about 0.50 to about 0.99; from about 0.50 to about 1.00; from about 0.60 to about 0.61; from about 0.60 to about 0.62; from about 0.60 to about 0.63; from about 0.60 to about 0.64; from about 0.60 to about 0.65; from about 0.60 to about 0.66; from about 0.60 to about 0.67; from about 0.60 to about 0.68; from about 0.60 to about 0.69; from about 0.60 to about 0.70; from about 0.60 to about 0.71; from about 0.60 to about 0.72; from about 0.60 to about 0.73; from about 0.60 to about 0.74; from about 0.60 to about 0.75; from about 0.60 to about 0.76; from about 0.60 to about 0.77; from about 0.60 to about 0.78; from about 0.60 to about 0.79; from about 0.60 to about 0.80; from about 0.60 to about 0.81; from about 0.60 to about 0.82; from about 0.60 to about 0.83; from about 0.60 to about 0.84; from about 0.60 to about 0.85; from about 0.60 to about 0.86; from about 0.60 to about 0.87; from about 0.60 to about 0.88; from about 0.60 to about 0.89; from about 0.60 to about 0.90; from about 0.60 to about 0.91; from about 0.60 to about

0.92; from about 0.60 to about 0.93; from about 0.60 to about 0.94; from about 0.60 to about 0.95; from about 0.60 to about 0.96; from about 0.60 to about 0.97; from about 0.60 to about 0.98; from about 0.60 to about 0.99; from about 0.60 to about 1.00; from about 0.70 to about 0.71; from about 0.70 to about 0.72; from about 0.70 to about 0.73; from about 0.70 to about 0.74; from about 0.70 to about 0.75; from about 0.70 to about 0.76; from about 0.70 to about 0.77; from about 0.70 to about 0.78; from about 0.70 to about 0.79; from about 0.70 to about 0.80; from about 0.70 to about 0.81; from about 0.70 to about 0.82; from about 0.70 to about 0.83; from about 0.70 to about 0.84; from about 0.70 to about 0.85; from about 0.70 to about 0.86; from about 0.70 to about 0.87; from about 0.70 to about 0.88; from about 0.70 to about 0.89; from about 0.70 to about 0.90; from about 0.70 to about 0.91; from about 0.70 to about 0.92; from about 0.70 to about 0.93; from about 0.70 to about 0.94; from about 0.70 to about 0.95; from about 0.70 to about 0.96; from about 0.70 to about 0.97; from about 0.70 to about 0.98; from about 0.70 to about 0.99; from about 0.70 to about 1.00; from about 0.80 to about 0.80; from about 0.80 to about 0.81; from about 0.80 to about 0.82; from about 0.80 to about 0.83; from about 0.80 to about 0.84; from about 0.80 to about 0.85; from about 0.80 to about 0.86; from about 0.80 to about 0.87; from about 0.80 to about 0.88; from about 0.80 to about 0.89; from about 0.80 to about 0.90; from about 0.80 to about 0.91; from about 0.80 to about 0.92; from about 0.80 to about 0.93; from about 0.80 to about 0.94; from about 0.80 to about 0.95; from about 0.80 to about 0.96; from about 0.80 to about 0.97; from about 0.80 to about 0.98; from about

0.80 to about 0.99; from about 0.80 to about 1.00; from about 0.90 to about 0.91; from about 0.90 to about 0.92; from about 0.90 to about 0.93; from about 0.90 to about 0.94; from about 0.90 to about 0.95; from about 0.90 to about 0.96; from about 0.90 to about 0.97; from about 0.90 to about 0.98; from about 0.90 to about 0.99; and, from about 0.90 to about 1.00.

112. The method of claim 1 wherein said active material particles have a nitrogen adsorption Brunauer-Emmett-Teller (BET) method surface area that is greater than $10 \text{ m}^2/\text{g}$.

113. The method of claim 1 wherein said active material particles have a nitrogen adsorption BET method surface area that is greater than $20 \text{ m}^2/\text{g}$.

114. The method of claim 1 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $10 \text{ m}^2/\text{g}$.

115. The method of claim 1 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $15 \text{ m}^2/\text{g}$.

116. The method of claim 1 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $20 \text{ m}^2/\text{g}$.

117. The method of claim 1 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $30 \text{ m}^2/\text{g}$.

118. The method of claim 1 wherein the active material particles have a cross-sectional dimension ranging from about 50 μm to about 125 μm .
119. The method of claim 1 wherein the active material particles have a cross-sectional dimension ranging from about 80 μm to about 100 μm .
120. The method of claim 1 wherein the active material particles have a pore volume fraction ranging from about 40% to about 70% by volume.
121. The method of claim 1 wherein said active material particles reversibly stores lithium ions.
122. The method of claim 1 wherein said active material particles comprise a battery electrode active material.
123. The method of claim 1 wherein said active material particles comprise nanometer scale sized active material particles.
124. The method of claim 1 wherein said active material particles comprise nano-structured materials.
125. The method of claim 1 wherein said active material particles contain micrometer scale sized active material particles.

126. The method of claim 1 wherein said active material particles comprise an anode active material capable of reversibly storing an ion.

127. The method of claim 1 wherein said active material comprises an anode active material selected from the group comprising: carbon; graphite; graphite coated graphite; graphene; mesocarbon micobeads; carbon nanotubes; silicon; porous silicon; nanostructured silicon; nanometer scale silicon; micrometer scale silicon; alloys containing silicon; carbon coated silicon; carbon nanotube coated silicon; manganese vanadate; manganese molybdate; sulfur oxide; highly oriented pyrolytic graphite; tin; tin oxide; alloys containing tin; antimony, tin antimony; lithium metal; and $\text{Li}_4\text{Ti}_5\text{O}_{12}$.

128. The method of claim 1 wherein said electrically conductive particles comprise at least one metal element.

129. The method of claim 128 wherein said metal element is selected from the group consisting of: ruthenium; rhodium; palladium; silver; osmium; iridium; platinum; copper; aluminum; and, gold.

130. The method of claim 128 wherein said metal comprising electrically conductive particles are filamentous.

131. The method of claim 1 wherein said electrically conductive particles comprise carbon.

132. The method of claim 131 wherein said carbon comprises a carbon form selected from the group consisting of: carbon; amorphous carbon; carbon black; carbon nanotubes; single-walled carbon nanotubes; multi-walled carbon nanotubes; carbon nanorods; carbon nanofoam; nanostructured carbon; carbon nanobuds; Buckminster fullerenes; linear acetylenic carbon; metallic carbon; Lonsdaleite; diamond; graphite; graphite coated graphite; graphene; and, mesocarbon microbeads.

133. The method of claim 131 wherein said carbon comprises carbon nanotubes.

134. The method of claim 131 wherein said carbon comprises graphitic carbon.

135. The method of claim 131 wherein said carbon comprises carbon black.

136. The method of claim 1 wherein said active material suspension further comprises a binder.

137. The method of claim 136 wherein said binder is a polymer binder.

138. The method of claim 137 wherein said polymer binder is selected from the group of binders consisting of: acacia gum; acrylonitrile/butadiene rubber (NBR); agarose; alginate; butyl rubber; carboxymethylcellulose; carrageenan; casein; ethylene/propylene/diene terpolymer (EPDM); gelatin; guar gum; hydroxymethylcellulose; hydroxyethylcellulose; hydroxyl ethyl methyl cellulose; hydroxypropylcellulose (HPC); isobutylene-maleic

anyhydride copolymer; ethylene-maleic anyhydride copolymer; pectin; polyethylene glycol; polyacrylonitrile; polyacrylic acid; poly(ϵ -caprolactone)(PLL); polyimide; polyethylene (PE); polyethyleneoxide (PEO); polyglycolide (PGA); poly(lactide); polypropylene oxide (PPO); polypropylene (PP); polyurethane; polyvinyl alcohol; neoprene; polyisobutylene (PIB); starch; styrene/acrylonitrile/styrene (SIS) block copolymers; styrene/butadiene rubber (SBR); styrene/butadiene/styrene (SBS) block copolymers; styrene-maleic anyhydride copolymer; tragacanth: and, xanthum gum.

139. The method of claim 1 wherein said active material suspension further comprises carboxymethylcellulose/styrene butadiene rubber.

140. An electrode comprising:

- a. a substrate having a conductive surface;
- b. a plurality of electrode matrix material layers, said layers being sequentially layered upon said conductive surface; said electrode matrix material comprising:
 - i. active material particles; and,
 - ii. electrically conductive particles;wherein each of said plurality of electrode matrix material layers is attached to its preceding electrode matrix material layer;
wherein one of said plurality of electrode matrix material layers is attached to, and in electrical communication with, said substrate surface;

wherein each of said plurality of electrode matrix material layers is in electrical communication with each adjacent electrode matrix material layer;

wherein each of said plurality of electrode matrix material layers is in ion communication with each adjacent electrode matrix material layer.

141. The electrode of claim 140 further comprising:

- c) one or more conductive layers interspersed between at least two adjacent electrode matrix material layers.

142. The electrode of claim 141 wherein said one or more conductive layers comprises conductive particles.

143. The electrode of claim 140 wherein said conductive particles comprise metal containing particles.

144. The electrode of claim 140 wherein said conductive particles comprise carbon.

145. The electrode of claim 144 wherein said carbon is a form of carbon selected from the group consisting of: carbon; graphite; graphene; carbon nanotubes; carbon nanoballs, carbon nanobuds; single-walled carbon nanotubes; multi-walled carbon nanotubes, carbon black; conductive carbon black; and, acetylene-black.

146. The electrode of claim 140 wherein said conductive particles comprises a mixture of two or more different types of conductive particles.

147. The electrode of claim 146 wherein each of said electrode matrix material layers attaches to said adjacent electrode matrix material layers to form a boundary between said electrode matrix material layers.

148. The electrode of claim 147 wherein said boundary is detectable using electron microscopy.

149. The electrode of claim 147 wherein said boundary is discrete.

150. The electrode of claim 147 wherein said boundary is amorphous.

151. The electrode of claim 147 wherein said electrode matrix material layers bond to form a monolithic electrode structure.

152. The electrode of claim 147 wherein said electrode matrix material layers bond without forming a monolithic electrode structure.

153. The electrode of claim 140 further comprising a carbon nanotube containing first layer.

154. The electrode of claim 140 further comprising binder material.
155. The electrode of claim 140 wherein said electrode is doped.
156. The electrode of claim 140 wherein said electrode has been calendared.
157. The electrode of claim 140 wherein said substrate comprises a metal.
158. The electrode of claim 140 wherein said substrate comprises aluminum.
159. The electrode of claim 140 wherein said substrate comprises copper.
160. The electrode of claim 140 wherein said substrate comprises nickel.
161. The electrode of claim 140 wherein said substrate comprises a non-metal.
162. The electrode of claim 140 wherein said substrate comprises a polymer.
163. The electrode of claim 162 wherein said substrate comprises a polymer selected from the group consisting of: acrylonitrile butadiene styrene (ABS); allylmethacrylate; polyacrylonitrile (PAN); acrylic; polyamide; polyaramides; polyacrylamide; polyvinylcaprolactam; polypropylene oxide (PPO); polystyrene (PS); polyvinylidene fluoride-trifluoroethylene (PVDF-TrFE); polyvinylidene fluoride – tetrafluoroethylene (PVDF-TFE); polybutadiene; poly(butylene terephthalate) (PBT); polycarbonate;

polychloroprene; poly(cis-1,4-isoprene); polyester; poly(ether sulfone) (PES, PES/PEES); poly(ether-ether ketone)s (PEEK, PES/PEEK); polyethylene (PE); poly(ethylene glycol) (PEG); poly(ethylene terephthalate) (PET); polyethylene oxide (PEO); poly(2-hydroxymethylmethacrylate); polypropylene (PP); poly(trans-1,4-isoprene); poly (methyl acrylate); poly (methyl methacrylate); polytetrafluoroethylene (PTFE); poly(trimethylene terephthalate) (PTT); polyurethane (PU); polyvinyl butyral (PVB); polyvinylchloride (PVC); polyvinylidenedifluoride (PVDF); poly(vinyl pyrrolidone) (PVP); nylon; silicone rubbers; sodium polyacrylate; styrene-acrylonitrile resin (SAN); polymeric organosilicon; polydimethylsiloxane; and, ethylene glycol dimethacrylate.

164. The electrode of claim 162 wherein said polymer is polypropylene and said support is a porous film comprising polypropylene.

165. The electrode of claim 162 wherein said support comprises three layers, each layer comprising a polymer material.

166. The electrode of claim 165 wherein said three layers comprises a porous polyethylene sheet sandwiched between two porous polypropylene sheets.

167. The electrode of claim 162 wherein said support is an ion permeable electrically non-conductive battery separator.

168. The electrode of claim 140 wherein said substrate comprises a non-woven material.

169. The electrode of claim 140 wherein said substrate comprises a woven material.
170. The electrode of claim 140 wherein said substrate comprises pores.
171. The electrode of claim 140 wherein said substrate is a foil.
172. The electrode of claim 140 wherein said substrate is a film.
173. The electrode of claim 140 wherein said substrate comprises a plurality of layers.
174. The electrode of claim 173 wherein two or more of said plurality of layers are different.
175. The electrode of claim 173 wherein two or more of said plurality of layers are the same.
176. The electrode of claim 140 wherein said active material particles comprise an anode active material capable of reversibly storing an ion.
177. The electrode of claim 140 wherein said active material particles further comprise lithium ions stored therein.

178. The electrode of claim 140 wherein said active material particles comprise a cathode active material capable of reversibly storing an ion.

179. The electrode of claim 140 wherein said active material comprises a cathode active material selected from the group consisting of: LiFePO_4 ; LiCoO_2 ; LiMnO_2 ; LiMn_2O_4 ; $\text{LiMn}_{1/2}\text{Ni}_{1/2}\text{O}_2$; $\text{LiFe}(\text{Zr})\text{PO}_4$; and, $\text{Li}(\text{Ni}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3})\text{O}_2$.

180. The electrode of claim 140 wherein said active material particles comprise a material selected from the list consisting of: Li_3BiF_3 ; $\text{Li}_3\text{Bi}_2\text{O}_3$; LiCoO_2 ; Li_2CoF_2 ; Li_3CrF_3 ; $\text{Li}_3\text{Cr}_2\text{O}_3$; Li_2CuF_2 ; Li_2CuO ; Li_2CuS ; Li_3FeF_3 ; $\text{Li}_3\text{Fe}_2\text{O}_3$; Li_2FeF_2 ; Li_2FeO ; Li_2FeS ; Li_2MnF_2 ; Li_2MnO ; LiMn_2O_4 ; Li_3MnF_3 ; $\text{Li}_3\text{Mn}_2\text{O}_3$; Li_2MnS ; Li_2NiF_2 ; LiNiO_2 ; Li_2NiO ; Li_3VF_3 ; and, $\text{Li}_3\text{V}_2\text{O}_3$.

181. The electrode of claim 140 wherein said active material particles comprise an oxide of a metal selected from the group consisting of: aluminum; chromium; cobalt; iron; nickel; magnesium; manganese; molybdenum; titanium; and, vanadium.

182. The electrode of claim 140 wherein said active material particles comprise a lithium-transition metal-phosphate compound doped with a material selected from the group consisting of: metals, metalloids, and, halogens.

183. The met electrode of claim 140 wherein said active material particles comprise an olivine structure LiMPO_4 compound, where M is selected from the group of metals consisting of: vanadium, chromium, manganese, iron, cobalt, and nickel.

184. The electrode of claim 140 wherein said active material particles comprise an olivine structure LiMPO_4 compound having lithium sites with deficiencies, said deficiencies being compensated by the addition of a metal or metalloid.

185. The electrode of claim 140 wherein said active material particles comprise an olivine structure LiMPO_4 having metal sites, wherein at least a portion of said metal sites are doped.

186. The electrode of claim 140 wherein said active material particles comprise an olivine structure LiMPO_4 compound having oxygen sites, said oxygen sites having deficiencies compensated by the addition of a halogen.

187. The electrode of claim 140 wherein said active material particles comprises $\text{Li}_x\text{NyM}_{1-y}\text{O}_2$, wherein M comprises a metal selected from the group consisting of: a transitional metal; titanium; vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc; and aluminum, and, $0.05 \leq x \leq 1.10$ and $0.5 \leq y \leq 1.0$.

188. The electrode of claim 140 wherein said active material particles comprise a titanium containing compound selected from the group consisting of: Li_2TiO_3 ; $\text{Li}_4\text{Ti}_5\text{O}_{12}$; $\text{Li}_7\text{Ti}_5\text{O}_{12}$; $\text{Li}_4\text{Ti}_{5-x}\text{M}_x\text{O}_{12}$; $\text{Li}_4\text{Ti}_5\text{-ZM}_{z1}^1\text{M}_{z2}^2\text{M}_{z3}^3 \dots \text{M}_{zk}^k\text{O}_{12}$; $\text{Li}_4\text{Ti}_{5-x-b}\text{M}_x\text{B}_b\text{O}_{12}$; $\text{Li}_{3+a}\text{Ti}_{6-a-x}\text{M}_x\text{O}_{12}$; $\text{Li}_{3+a}\text{Ti}_{6-a-x-b}\text{M}_x\text{B}_b\text{O}_{12}$, and $\text{Li}_{4-c}\text{Mg}_c\text{Ti}_{5-x}\text{M}_x\text{O}_{12}$, wherein Z has a value from about 0.1 to about 2.5; $z_1, z_2, z_3, \dots, z_k$ independently have a value from about 0 to about 2.5; Z and $z_1, z_2, z_3, \dots, z_k$ satisfy the equation: $Z = z_1 + z_2 + z_3 + \dots + z_k$; x has a value from about 0.1 to about 2.5, a

has a value from about 0 to about 1, b has a value from about 0 to about 2.5, and c has a value from about 0 to about 1.5; M is one or more cations selected from the group of V, Cr, Nb, Mo, Ta, and W; $M_1, M_2, M_3, \dots, M_k$ are cations independently selected from the group of V, Cr, Nb, Mo, Ta, and W; and B is one or more cations selected from the group of Zr, Ce, Si, and Ge.

189. The electrode of claim 140 wherein said active material particles comprise a poor metal selected from the group consisting of: aluminium; antimony; bismuth; gallium; germanium; indium; lead; polonium; thallium; and, tin.

190. The electrode of claim 140 wherein said active material particles comprise a pnictogen selected from the group consisting of: nitrogen; phosphorus; arsenic; antimony; and, bismuth.

191. The electrode of claim 140 wherein said active material particles comprise lithium metal.

192. The electrode of claim 191 wherein said active material particles further comprise a non-lithium metal selected from the group of metals consisting of: aluminum; chromium; cobalt; iron; nickel; magnesium; manganese; molybdenum; titanium; and, vanadium.

193. The electrode of claim 140 wherein the active material particles comprise an olivine lithium metal phosphate material having the formula $LixM'yM''zPO_4$,

wherein M' comprises a metal selected from the group consisting of:
manganese and iron,

wherein M'' comprises a metal selected from the group consisting of:
manganese; cobalt; and, nickel,
wherein M' is not the same as M'', and,
wherein x is greater than or equal to 0, and x is less than or equal to 1.2; y is
greater than or equal to 0.7, and y is less than or equal to 0.95; z is greater than
or equal to 0.02, and z is greater than or equal to 0.3; and, the sum of y and z is
greater than or equal to 0.8, and the sum of y and z is less than or equal to 1.2.

194. The electrode of claim 193, wherein z is greater than or equal to 0.02, and z is less than or equal to 0.1.

195. The electrode of claim 193, wherein the sum of y and z equals 1.

196. The electrode of claim 193, wherein M' is iron, and z is greater than or equal to 0.02, and z is less than or equal to 0.1.

197. The electrode of claim 193, wherein the sum of y and z equals 1.

198. The electrode of claim 193, wherein the sum of y and z is greater than or equal to 0.8, and the sum of y and z is less than or equal to 1.

199. The electrode of claim 140 wherein the active material particles comprise a lithium transition metal phosphate material having an overall composition of $\text{Li}_{1-x}\text{MPO}_4$, wherein M

comprises at least one first row transition metal selected from the group consisting of titanium, vanadium, chromium, manganese, iron, cobalt and nickel, and wherein in use x ranges from 0 to 1.

200. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0.1 to about 0.3.

201. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.15 at room temperature.

202. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to at least about 0.07 at room temperature.

203. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.05 at room temperature.

204. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.8.

205. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.9.

206. The electrode of claim 199 wherein M is iron and the active material particles can form a stable solid solution when x ranges from about 0 to about 0.95.

207. The electrode of claim 140 wherein said active material comprises a material having the formula $\text{Li}_{1-x}\text{M}_x\text{FePO}_4$,

wherein M is a dopant selected from the group consisting of: titanium;

vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc;

zirconium; niobium; molybdenum; silver; and, tungsten, and,

wherein x is a number selected from the group consisting of: about 0.00; about

0.01; about 0.02; about 0.03; about 0.04; about 0.05; about 0.06; about 0.07;

about 0.08; about 0.09; about 0.10; about 0.11; about 0.12; about 0.13; about

0.14; about 0.15; about 0.16; about 0.17; about 0.18; about 0.19; about 0.20;

about 0.21; about 0.22; about 0.23; about 0.24; about 0.25; about 0.26; about

0.27; about 0.28; about 0.29; about 0.30; about 0.31; about 0.32; about 0.33;

about 0.34; about 0.35; about 0.36; about 0.37; about 0.38; about 0.39; about

0.40; about 0.41; about 0.42; about 0.43; about 0.44; about 0.45; about 0.46;

about 0.47; about 0.48; about 0.49; about 0.50; about 0.51; about 0.52; about

0.53; about 0.54; about 0.55; about 0.56; about 0.57; about 0.58; about 0.59;

about 0.60; about 0.61; about 0.62; about 0.63; about 0.64; about 0.65; about

0.66; about 0.67; about 0.68; about 0.69; about 0.70; about 0.71; about 0.72;

about 0.73; about 0.74; about 0.75; about 0.76; about 0.77; about 0.78; about

0.79; about 0.80; about 0.81; about 0.82; about 0.83; about 0.84; about 0.85;

about 0.86; about 0.87; about 0.88; about 0.89; about 0.90; about 0.91; about

0.92; about 0.93; about 0.94; about 0.95; about 0.96; about 0.97; about 0.98;
about 0.99; and, about 1.00.

208. The electrode of claim 140 wherein the active material comprises a material having the formula $\text{Li}_{1-x}\text{M}_x\text{FePO}_4$,

wherein M is a metal selected from the group consisting of: titanium;

vanadium; chromium; manganese; iron; cobalt; nickel; copper; zinc;

zirconium; niobium; molybdenum; silver; and, tungsten, and,

wherein x is a number range selected from the group consisting of: from about 0.00 to about 0.01; from about 0.00 to about 0.02; from about 0.00 to about 0.03; from about 0.00 to about 0.04; from about 0.00 to about 0.05; from about 0.00 to about 0.06; from about 0.00 to about 0.07; from about 0.00 to about 0.08; from about 0.00 to about 0.09; from about 0.00 to about 0.10; from about 0.00 to about 0.11; from about 0.00 to about 0.12; from about 0.00 to about 0.13; from about 0.00 to about 0.14; from about 0.00 to about 0.15; from about 0.00 to about 0.16; from about 0.00 to about 0.17; from about 0.00 to about 0.18; from about 0.00 to about 0.19; from about 0.00 to about 0.20; from about 0.00 to about 0.21; from about 0.00 to about 0.22; from about 0.00 to about 0.23; from about 0.00 to about 0.24; from about 0.00 to about 0.25; from about 0.00 to about 0.26; from about 0.00 to about 0.27; from about 0.00 to about 0.28; from about 0.00 to about 0.29; from about 0.00 to about 0.30; from about 0.00 to about 0.31; from about 0.00 to about 0.32; from about 0.00 to about 0.33; from about 0.00 to about 0.34; from about 0.00 to about 0.35; from about

0.00 to about 0.36; from about 0.00 to about 0.37; from about 0.00 to about 0.38; from about 0.00 to about 0.39; from about 0.00 to about 0.40; from about 0.00 to about 0.41; from about 0.00 to about 0.42; from about 0.00 to about 0.43; from about 0.00 to about 0.44; from about 0.00 to about 0.45; from about 0.00 to about 0.46; from about 0.00 to about 0.47; from about 0.00 to about 0.48; from about 0.00 to about 0.49; from about 0.00 to about 0.50; from about 0.00 to about 0.51; from about 0.00 to about 0.52; from about 0.00 to about 0.53; from about 0.00 to about 0.54; from about 0.00 to about 0.55; from about 0.00 to about 0.56; from about 0.00 to about 0.57; from about 0.00 to about 0.58; from about 0.00 to about 0.59; from about 0.00 to about 0.60; from about 0.00 to about 0.61; from about 0.00 to about 0.62; from about 0.00 to about 0.63; from about 0.00 to about 0.64; from about 0.00 to about 0.65; from about 0.00 to about 0.66; from about 0.00 to about 0.67; from about 0.00 to about 0.68; from about 0.00 to about 0.69; from about 0.00 to about 0.70; from about 0.00 to about 0.71; from about 0.00 to about 0.72; from about 0.00 to about 0.73; from about 0.00 to about 0.74; from about 0.00 to about 0.75; from about 0.00 to about 0.76; from about 0.00 to about 0.77; from about 0.00 to about 0.78; from about 0.00 to about 0.79; from about 0.00 to about 0.80; from about 0.00 to about 0.81; from about 0.00 to about 0.82; from about 0.00 to about 0.83; from about 0.00 to about 0.84; from about 0.00 to about 0.85; from about 0.00 to about 0.86; from about 0.00 to about 0.87; from about 0.00 to about 0.88; from about 0.00 to about 0.89; from about 0.00 to about 0.90; from about 0.00 to about 0.91; from about 0.00 to about 0.92; from about 0.00 to about

0.93; from about 0.00 to about 0.94; from about 0.00 to about 0.95; from about 0.00 to about 0.96; from about 0.00 to about 0.97; from about 0.00 to about 0.98; from about 0.00 to about 0.99; from about 0.00 to about 0.10; from about 0.10 to about 0.11; from about 0.10 to about 0.12; from about 0.10 to about 0.13; from about 0.10 to about 0.14; from about 0.10 to about 0.15; from about 0.10 to about 0.16; from about 0.10 to about 0.17; from about 0.10 to about 0.18; from about 0.10 to about 0.19; from about 0.10 to about 0.20; from about 0.10 to about 0.21; from about 0.10 to about 0.22; from about 0.10 to about 0.23; from about 0.10 to about 0.24; from about 0.10 to about 0.25; from about 0.10 to about 0.26; from about 0.10 to about 0.27; from about 0.10 to about 0.28; from about 0.10 to about 0.29; from about 0.10 to about 0.30; from about 0.10 to about 0.31; from about 0.10 to about 0.32; from about 0.10 to about 0.33; from about 0.10 to about 0.34; from about 0.10 to about 0.35; from about 0.10 to about 0.36; from about 0.10 to about 0.37; from about 0.10 to about 0.38; from about 0.10 to about 0.39; from about 0.10 to about 0.40; from about 0.10 to about 0.41; from about 0.10 to about 0.42; from about 0.10 to about 0.43; from about 0.10 to about 0.44; from about 0.10 to about 0.45; from about 0.10 to about 0.46; from about 0.10 to about 0.47; from about 0.10 to about 0.48; from about 0.10 to about 0.49; from about 0.10 to about 0.50; from about 0.10 to about 0.51; from about 0.10 to about 0.52; from about 0.10 to about 0.53; from about 0.10 to about 0.54; from about 0.10 to about 0.55; from about 0.10 to about 0.56; from about 0.10 to about 0.57; from about 0.10 to about 0.58; from about 0.10 to about 0.59; from about 0.10 to about 0.60; from about

0.10 to about 0.61; from about 0.10 to about 0.62; from about 0.10 to about 0.63; from about 0.10 to about 0.64; from about 0.10 to about 0.65; from about 0.10 to about 0.66; from about 0.10 to about 0.67; from about 0.10 to about 0.68; from about 0.10 to about 0.69; from about 0.10 to about 0.70; from about 0.10 to about 0.71; from about 0.10 to about 0.72; from about 0.10 to about 0.73; from about 0.10 to about 0.74; from about 0.10 to about 0.75; from about 0.10 to about 0.76; from about 0.10 to about 0.77; from about 0.10 to about 0.78; from about 0.10 to about 0.79; from about 0.10 to about 0.80; from about 0.10 to about 0.81; from about 0.10 to about 0.82; from about 0.10 to about 0.83; from about 0.10 to about 0.84; from about 0.10 to about 0.85; from about 0.10 to about 0.86; from about 0.10 to about 0.87; from about 0.10 to about 0.88; from about 0.10 to about 0.89; from about 0.10 to about 0.90; from about 0.10 to about 0.91; from about 0.10 to about 0.92; from about 0.10 to about 0.93; from about 0.10 to about 0.94; from about 0.10 to about 0.95; from about 0.10 to about 0.96; from about 0.10 to about 0.97; from about 0.10 to about 0.98; from about 0.10 to about 0.99; from about 0.10 to about 1.00; from about 0.20 to about 0.21; from about 0.20 to about 0.22; from about 0.20 to about 0.23; from about 0.20 to about 0.24; from about 0.20 to about 0.25; from about 0.20 to about 0.26; from about 0.20 to about 0.27; from about 0.20 to about 0.28; from about 0.20 to about 0.29; from about 0.20 to about 0.30; from about 0.20 to about 0.31; from about 0.20 to about 0.32; from about 0.20 to about 0.33; from about 0.20 to about 0.34; from about 0.20 to about 0.35; from about 0.20 to about 0.36; from about 0.20 to about 0.37; from about 0.20 to about

0.38; from about 0.20 to about 0.39; from about 0.20 to about 0.40; from about 0.20 to about 0.41; from about 0.20 to about 0.42; from about 0.20 to about 0.43; from about 0.20 to about 0.44; from about 0.20 to about 0.45; from about 0.20 to about 0.46; from about 0.20 to about 0.47; from about 0.20 to about 0.48; from about 0.20 to about 0.49; from about 0.20 to about 0.50; from about 0.20 to about 0.51; from about 0.20 to about 0.52; from about 0.20 to about 0.53; from about 0.20 to about 0.54; from about 0.20 to about 0.55; from about 0.20 to about 0.56; from about 0.20 to about 0.57; from about 0.20 to about 0.58; from about 0.20 to about 0.59; from about 0.20 to about 0.60; from about 0.20 to about 0.61; from about 0.20 to about 0.62; from about 0.20 to about 0.63; from about 0.20 to about 0.64; from about 0.20 to about 0.65; from about 0.20 to about 0.66; from about 0.20 to about 0.67; from about 0.20 to about 0.68; from about 0.20 to about 0.69; from about 0.20 to about 0.70; from about 0.20 to about 0.71; from about 0.20 to about 0.72; from about 0.20 to about 0.73; from about 0.20 to about 0.74; from about 0.20 to about 0.75; from about 0.20 to about 0.76; from about 0.20 to about 0.77; from about 0.20 to about 0.78; from about 0.20 to about 0.79; from about 0.20 to about 0.80; from about 0.20 to about 0.81; from about 0.20 to about 0.82; from about 0.20 to about 0.83; from about 0.20 to about 0.84; from about 0.20 to about 0.85; from about 0.20 to about 0.86; from about 0.20 to about 0.87; from about 0.20 to about 0.88; from about 0.20 to about 0.89; from about 0.20 to about 0.90; from about 0.20 to about 0.91; from about 0.20 to about 0.92; from about 0.20 to about 0.93; from about 0.20 to about 0.94; from about 0.20 to about 0.95; from about

0.20 to about 0.96; from about 0.20 to about 0.97; from about 0.20 to about 0.98; from about 0.20 to about 0.99; from about 0.20 to about 1.00; from about 0.30 to about 0.31; from about 0.30 to about 0.32; from about 0.30 to about 0.33; from about 0.30 to about 0.34; from about 0.30 to about 0.35; from about 0.30 to about 0.36; from about 0.30 to about 0.37; from about 0.30 to about 0.38; from about 0.30 to about 0.39; from about 0.30 to about 0.40; from about 0.30 to about 0.41; from about 0.30 to about 0.42; from about 0.30 to about 0.43; from about 0.30 to about 0.44; from about 0.30 to about 0.45; from about 0.30 to about 0.46; from about 0.30 to about 0.47; from about 0.30 to about 0.48; from about 0.30 to about 0.49; from about 0.30 to about 0.50; from about 0.30 to about 0.51; from about 0.30 to about 0.52; from about 0.30 to about 0.53; from about 0.30 to about 0.54; from about 0.30 to about 0.55; from about 0.30 to about 0.56; from about 0.30 to about 0.57; from about 0.30 to about 0.58; from about 0.30 to about 0.59; from about 0.30 to about 0.60; from about 0.30 to about 0.61; from about 0.30 to about 0.62; from about 0.30 to about 0.63; from about 0.30 to about 0.64; from about 0.30 to about 0.65; from about 0.30 to about 0.66; from about 0.30 to about 0.67; from about 0.30 to about 0.68; from about 0.30 to about 0.69; from about 0.30 to about 0.70; from about 0.30 to about 0.71; from about 0.30 to about 0.72; from about 0.30 to about 0.73; from about 0.30 to about 0.74; from about 0.30 to about 0.75; from about 0.30 to about 0.76; from about 0.30 to about 0.77; from about 0.30 to about 0.78; from about 0.30 to about 0.79; from about 0.30 to about 0.80; from about 0.30 to about 0.81; from about 0.30 to about 0.82; from about 0.30 to about

0.83; from about 0.30 to about 0.84; from about 0.30 to about 0.85; from about 0.30 to about 0.86; from about 0.30 to about 0.87; from about 0.30 to about 0.88; from about 0.30 to about 0.89; from about 0.30 to about 0.90; from about 0.30 to about 0.91; from about 0.30 to about 0.92; from about 0.30 to about 0.93; from about 0.30 to about 0.94; from about 0.30 to about 0.95; from about 0.30 to about 0.96; from about 0.30 to about 0.97; from about 0.30 to about 0.98; from about 0.30 to about 0.99; from about 0.30 to about 1.00; from about 0.40 to about 0.40; from about 0.40 to about 0.41; from about 0.40 to about 0.42; from about 0.40 to about 0.43; from about 0.40 to about 0.44; from about 0.40 to about 0.45; from about 0.40 to about 0.46; from about 0.40 to about 0.47; from about 0.40 to about 0.48; from about 0.40 to about 0.49; from about 0.40 to about 0.50; from about 0.40 to about 0.51; from about 0.40 to about 0.52; from about 0.40 to about 0.53; from about 0.40 to about 0.54; from about 0.40 to about 0.55; from about 0.40 to about 0.56; from about 0.40 to about 0.57; from about 0.40 to about 0.58; from about 0.40 to about 0.59; from about 0.40 to about 0.60; from about 0.40 to about 0.61; from about 0.40 to about 0.62; from about 0.40 to about 0.63; from about 0.40 to about 0.64; from about 0.40 to about 0.65; from about 0.40 to about 0.66; from about 0.40 to about 0.67; from about 0.40 to about 0.68; from about 0.40 to about 0.69; from about 0.40 to about 0.70; from about 0.40 to about 0.71; from about 0.40 to about 0.72; from about 0.40 to about 0.73; from about 0.40 to about 0.74; from about 0.40 to about 0.75; from about 0.40 to about 0.76; from about 0.40 to about 0.77; from about 0.40 to about 0.78; from about 0.40 to about 0.79; from about

0.40 to about 0.80; from about 0.40 to about 0.81; from about 0.40 to about 0.82; from about 0.40 to about 0.83; from about 0.40 to about 0.84; from about 0.40 to about 0.85; from about 0.40 to about 0.86; from about 0.40 to about 0.87; from about 0.40 to about 0.88; from about 0.40 to about 0.89; from about 0.40 to about 0.90; from about 0.40 to about 0.91; from about 0.40 to about 0.92; from about 0.40 to about 0.93; from about 0.40 to about 0.94; from about 0.40 to about 0.95; from about 0.40 to about 0.96; from about 0.40 to about 0.97; from about 0.40 to about 0.98; from about 0.40 to about 0.99; from about 0.40 to about 1.00; from about 0.50 to about 0.51; from about 0.50 to about 0.52; from about 0.50 to about 0.53; from about 0.50 to about 0.54; from about 0.50 to about 0.55; from about 0.50 to about 0.56; from about 0.50 to about 0.57; from about 0.50 to about 0.58; from about 0.50 to about 0.59; from about 0.50 to about 0.60; from about 0.50 to about 0.61; from about 0.50 to about 0.62; from about 0.50 to about 0.63; from about 0.50 to about 0.64; from about 0.50 to about 0.65; from about 0.50 to about 0.66; from about 0.50 to about 0.67; from about 0.50 to about 0.68; from about 0.50 to about 0.69; from about 0.50 to about 0.70; from about 0.50 to about 0.71; from about 0.50 to about 0.72; from about 0.50 to about 0.73; from about 0.50 to about 0.74; from about 0.50 to about 0.75; from about 0.50 to about 0.76; from about 0.50 to about 0.77; from about 0.50 to about 0.78; from about 0.50 to about 0.79; from about 0.50 to about 0.80; from about 0.50 to about 0.81; from about 0.50 to about 0.82; from about 0.50 to about 0.83; from about 0.50 to about 0.84; from about 0.50 to about 0.85; from about 0.50 to about 0.86; from about 0.50 to about

0.87; from about 0.50 to about 0.88; from about 0.50 to about 0.89; from about 0.50 to about 0.90; from about 0.50 to about 0.91; from about 0.50 to about 0.92; from about 0.50 to about 0.93; from about 0.50 to about 0.94; from about 0.50 to about 0.95; from about 0.50 to about 0.96; from about 0.50 to about 0.97; from about 0.50 to about 0.98; from about 0.50 to about 0.99; from about 0.50 to about 1.00; from about 0.60 to about 0.61; from about 0.60 to about 0.62; from about 0.60 to about 0.63; from about 0.60 to about 0.64; from about 0.60 to about 0.65; from about 0.60 to about 0.66; from about 0.60 to about 0.67; from about 0.60 to about 0.68; from about 0.60 to about 0.69; from about 0.60 to about 0.70; from about 0.60 to about 0.71; from about 0.60 to about 0.72; from about 0.60 to about 0.73; from about 0.60 to about 0.74; from about 0.60 to about 0.75; from about 0.60 to about 0.76; from about 0.60 to about 0.77; from about 0.60 to about 0.78; from about 0.60 to about 0.79; from about 0.60 to about 0.80; from about 0.60 to about 0.81; from about 0.60 to about 0.82; from about 0.60 to about 0.83; from about 0.60 to about 0.84; from about 0.60 to about 0.85; from about 0.60 to about 0.86; from about 0.60 to about 0.87; from about 0.60 to about 0.88; from about 0.60 to about 0.89; from about 0.60 to about 0.90; from about 0.60 to about 0.91; from about 0.60 to about 0.92; from about 0.60 to about 0.93; from about 0.60 to about 0.94; from about 0.60 to about 0.95; from about 0.60 to about 0.96; from about 0.60 to about 0.97; from about 0.60 to about 0.98; from about 0.60 to about 0.99; from about 0.60 to about 1.00; from about 0.70 to about 0.71; from about 0.70 to about 0.72; from about 0.70 to about 0.73; from about 0.70 to about 0.74; from about

0.70 to about 0.75; from about 0.70 to about 0.76; from about 0.70 to about 0.77; from about 0.70 to about 0.78; from about 0.70 to about 0.79; from about 0.70 to about 0.80; from about 0.70 to about 0.81; from about 0.70 to about 0.82; from about 0.70 to about 0.83; from about 0.70 to about 0.84; from about 0.70 to about 0.85; from about 0.70 to about 0.86; from about 0.70 to about 0.87; from about 0.70 to about 0.88; from about 0.70 to about 0.89; from about 0.70 to about 0.90; from about 0.70 to about 0.91; from about 0.70 to about 0.92; from about 0.70 to about 0.93; from about 0.70 to about 0.94; from about 0.70 to about 0.95; from about 0.70 to about 0.96; from about 0.70 to about 0.97; from about 0.70 to about 0.98; from about 0.70 to about 0.99; from about 0.70 to about 1.00; from about 0.80 to about 0.80; from about 0.80 to about 0.81; from about 0.80 to about 0.82; from about 0.80 to about 0.83; from about 0.80 to about 0.84; from about 0.80 to about 0.85; from about 0.80 to about 0.86; from about 0.80 to about 0.87; from about 0.80 to about 0.88; from about 0.80 to about 0.89; from about 0.80 to about 0.90; from about 0.80 to about 0.91; from about 0.80 to about 0.92; from about 0.80 to about 0.93; from about 0.80 to about 0.94; from about 0.80 to about 0.95; from about 0.80 to about 0.96; from about 0.80 to about 0.97; from about 0.80 to about 0.98; from about 0.80 to about 0.99; from about 0.80 to about 1.00; from about 0.90 to about 0.91; from about 0.90 to about 0.92; from about 0.90 to about 0.93; from about 0.90 to about 0.94; from about 0.90 to about 0.95; from about 0.90 to about 0.96; from about 0.90 to about 0.97; from about 0.90 to about 0.98; from about 0.90 to about 0.99; and, from about 0.90 to about 1.00.

209. The electrode of claim 140 wherein said active material particles have a nitrogen adsorption Brunauer-Emmett-Teller (BET) method surface area that is greater than $10 \text{ m}^2/\text{g}$.

210. The electrode of claim 140 wherein said active material particles have a nitrogen adsorption BET method surface area that is greater than $20 \text{ m}^2/\text{g}$.

211. The electrode of claim 140 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $10 \text{ m}^2/\text{g}$.

212. The electrode of claim 140 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $15 \text{ m}^2/\text{g}$.

213. The electrode of claim 140 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $20 \text{ m}^2/\text{g}$.

214. The electrode of claim 140 wherein the active material particles have a nitrogen adsorption BET method surface area greater than $30 \text{ m}^2/\text{g}$.

215. The electrode of claim 140 wherein the active material particles have a cross-sectional dimension ranging from about $50 \text{ }\mu\text{m}$ to about $125 \text{ }\mu\text{m}$.

216. The electrode of claim 140 wherein the active material particles have a cross-sectional dimension ranging from about $80 \text{ }\mu\text{m}$ to about $100 \text{ }\mu\text{m}$.

217. The electrode of claim 140 wherein the active material particles have a pore volume fraction ranging from about 40% to about 70% by volume.

218. The electrode of claim 140 wherein said active material particles reversibly stores lithium ions.

219. The electrode of claim 140 wherein said active material particles comprise a battery electrode active material.

220. The electrode of claim 140 wherein said active material particles comprise nanometer scale sized active material particles.

221. The electrode of claim 140 wherein said active material particles comprise nano-structured materials.

222. The electrode of claim 140 wherein said active material particles contain micrometer scale sized active material particles.

223. The electrode of claim 140 wherein said active material particles comprise an anode active material capable of reversibly storing an ion.

224. The electrode of claim 140 wherein said active material comprises an anode active material selected from the group comprising: carbon; graphite; graphite coated graphite; graphene; mesocarbon micobeads; carbon nanotubes; silicon; porous silicon; nanostructured silicon; nanometer scale silicon; micrometer scale silicon; alloys containing silicon; carbon coated silicon; carbon nanotube coated silicon; tin; alloys containing tin; and $\text{Li}_4\text{Ti}_5\text{O}_{12}$.

225. The electrode of claim 140 wherein said electrically conductive particles comprise at least one metal element.

226. The electrode of claim 225 wherein said metal element is selected from the group consisting of: ruthenium; rhodium; palladium; silver; osmium; iridium; platinum; copper; aluminum; and, gold.

227. The electrode of claim 128 225 said metal comprising electrically conductive particles are filamentous.

228. The electrode of claim 140 wherein said electrically conductive particles comprise carbon.

229. The electrode of claim 228 wherein said carbon comprises a carbon form selected from the group consisting of: carbon; amorphous carbon; carbon black; carbon nanotubes; single-walled carbon nanotubes; multi-walled carbon nanotubes; carbon nanorods; carbon nanofoam; nanostructured carbon; carbon nanobuds; Buckminster fullerenes; linear

acetylenic carbon; metallic carbon; Lonsdaleite; diamond; graphite; graphite coated graphite; graphene; and, mesocarbon microbeads.

230. The electrode of claim 228 wherein said carbon comprises carbon nanotubes.

231. The electrode of claim 228 wherein said carbon comprises graphitic carbon.

232. The electrode of claim 228 wherein said carbon comprises carbon black.

233. The electrode of claim 140 wherein said active material suspension further comprises a binder.

234. The electrode of claim 233 wherein said binder is a polymer binder.

235. The electrode of claim 233 wherein said polymer binder is selected from the group of binders consisting of: acacia gum; acrylonitrile/butadiene rubber (NBR); agarose; alginate; butyl rubber; carboxymethylcellulose; carrageenan; casein; ethylene/prolylene/diene terpolymer (EPDM); gelatin; guar gum; hydroxymethylcellulose; hydroxyethylcellulose; hydroxyl ethyl methyl cellulose; hydroxypropylcellulose (HPC); isobutylene-maleic anhydride copolymer; ethylene-maleic anhydride copolymer; pectin; polyethylene glycol; polyacrylnitrile; polyacrylic acid; poly(ϵ -caprolactone)(PLL); polyimide; polyethylene (PE); polyethyleneoxide (PEO); polyglycolide (PGA); poly(lactide); polypropylene oxide (PPO); polypropylene (PP); polyurethane; polyvinyl alcohol; neoprene; polyisobutylene (PIB);

starch; styrene/acrylonitrile/styrene (SIS) block copolymers; styrene/butadiene rubber (SBR); styrene/butadiene/styrene (SBS) block copolymers; styrene-maleic anhydride copolymer; tragacanth; and, xanthum gum.

236. The electrode of claim 140 wherein said active material suspension further comprises carboxymethylcellulose/styrene butadiene rubber.

237. A system for making a battery electrode comprising:

- a) an unwinder;
- b) a rewinder; and,
- c) a plurality of spray/dry regions disposed between said unwinder and said rewinder, each spray/dry region comprising:
 - i) a sprayer in liquid communication with a liquid suspension source;
 - ii) a dryer in fluid communication with a gas source, said dryer being immediately preceded said spray region.

238. The system of claim 237 wherein said plurality of spray/dry regions comprises at least two spray/dry regions.

239. The system of claim 237 wherein said plurality of spray/dry regions comprises at least five spray/dry regions.

240. The system of claim 237 wherein said plurality of spray/dry regions comprises at least ten spray/dry regions.

241. The system of claim 237 wherein said plurality of spray/dry regions comprises at least twenty spray/dry regions.

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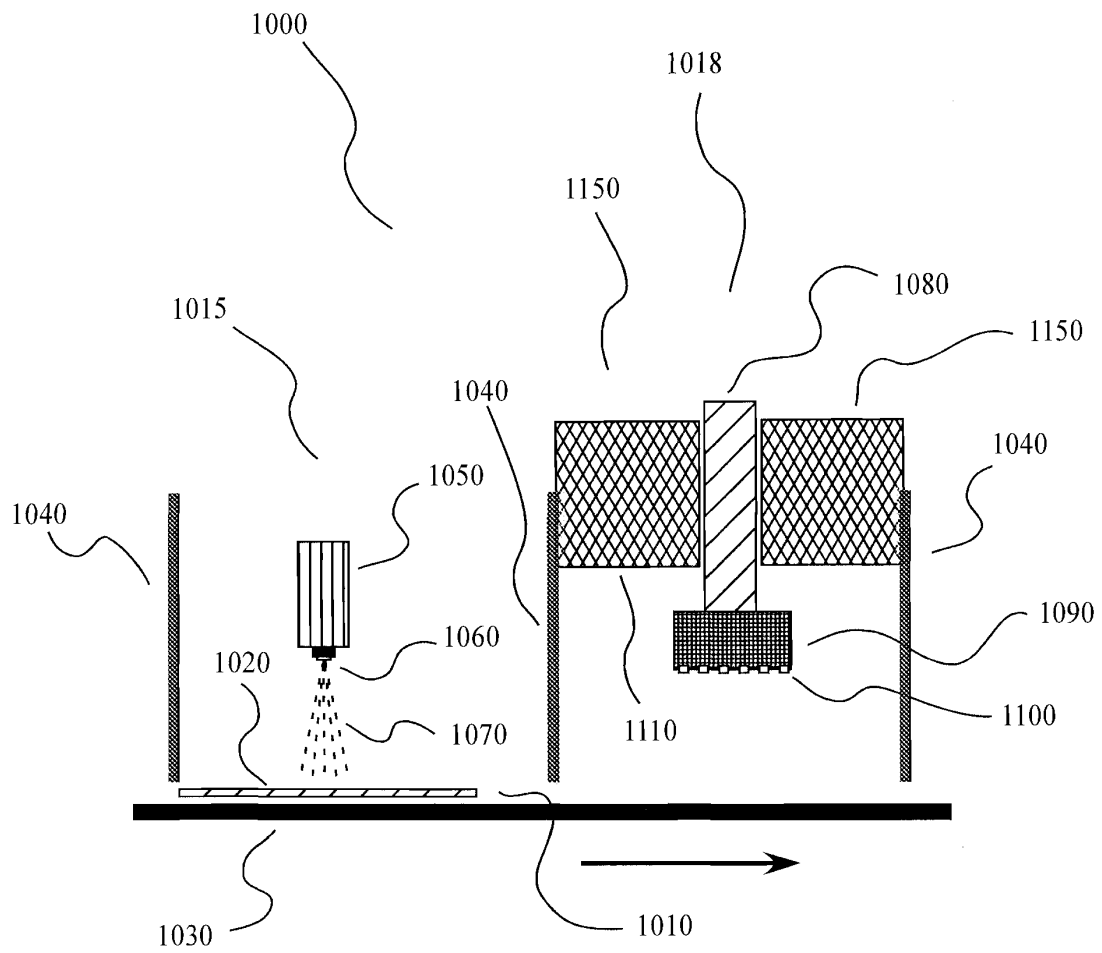


FIG 1A

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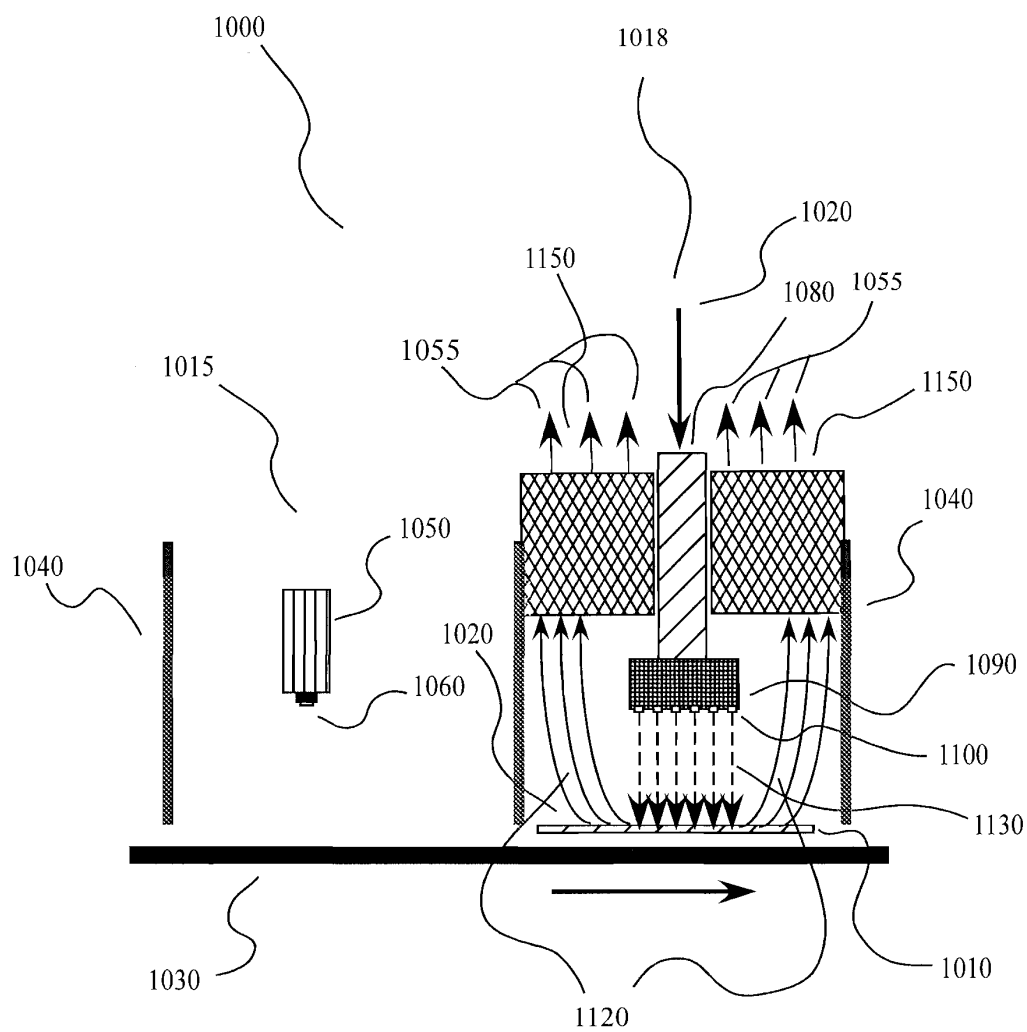


FIG 1B

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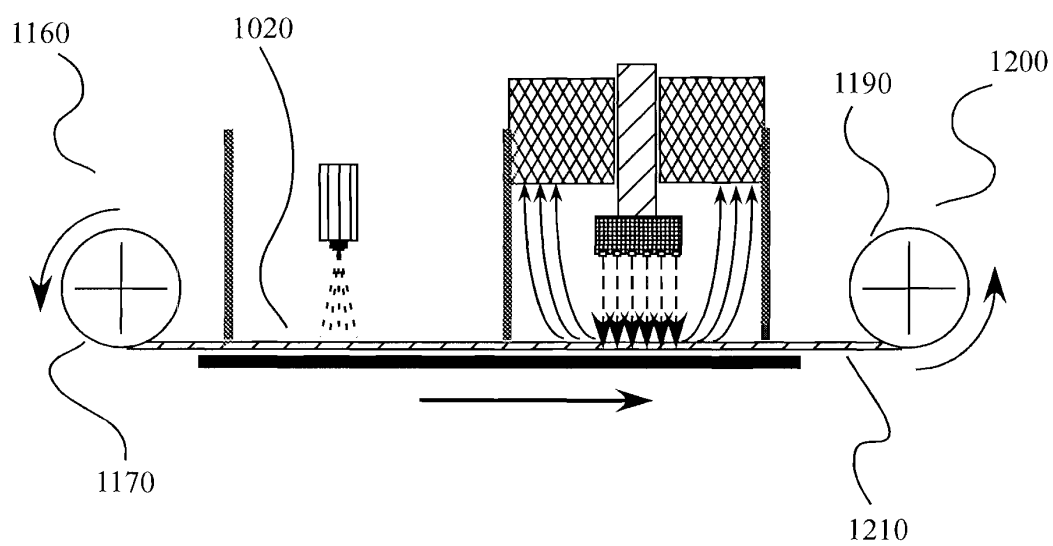


FIG 2

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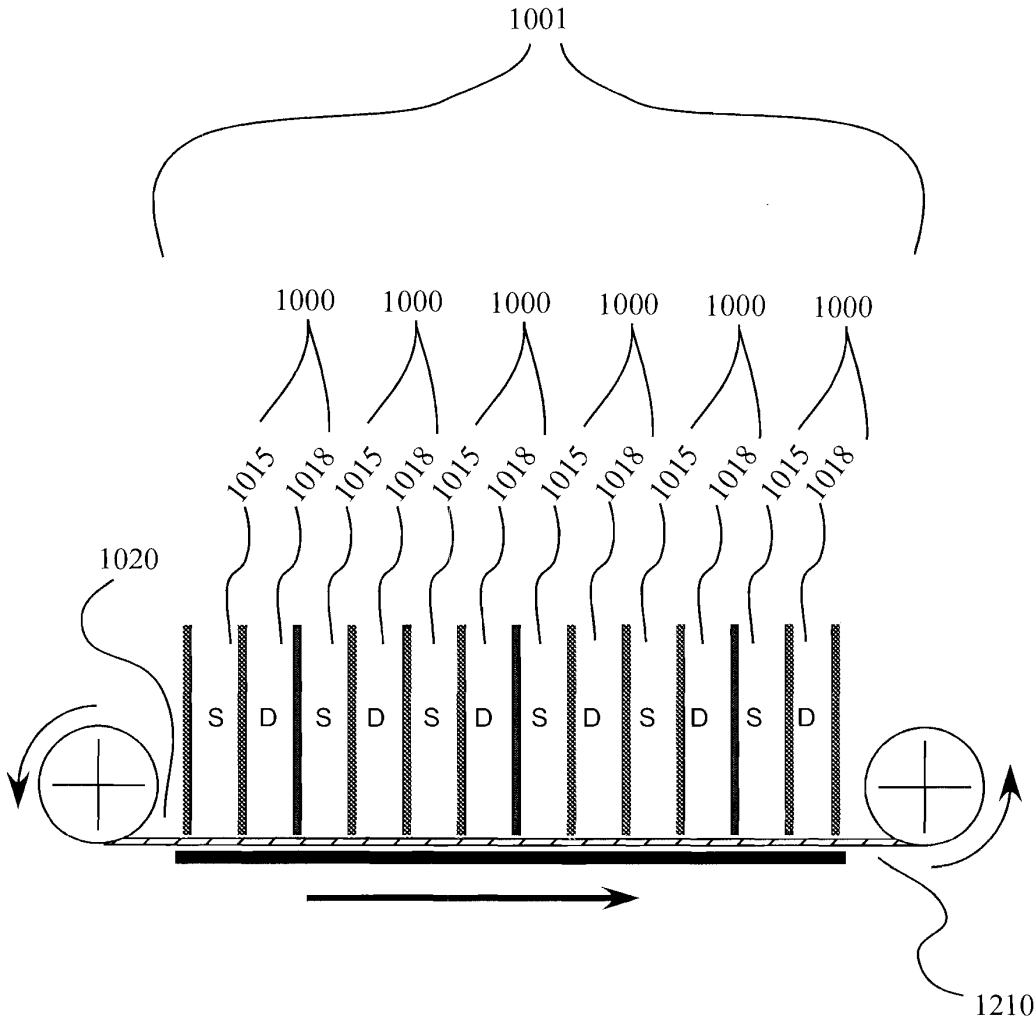


FIG 3

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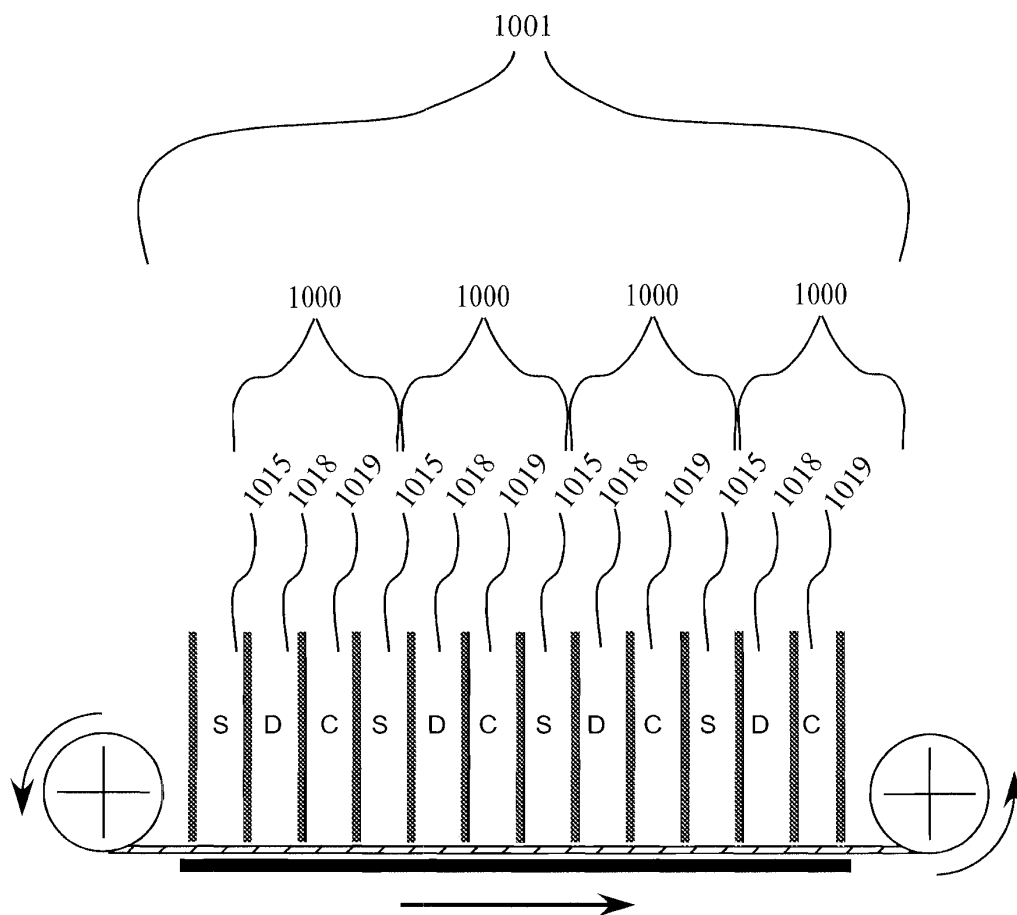


FIG 4

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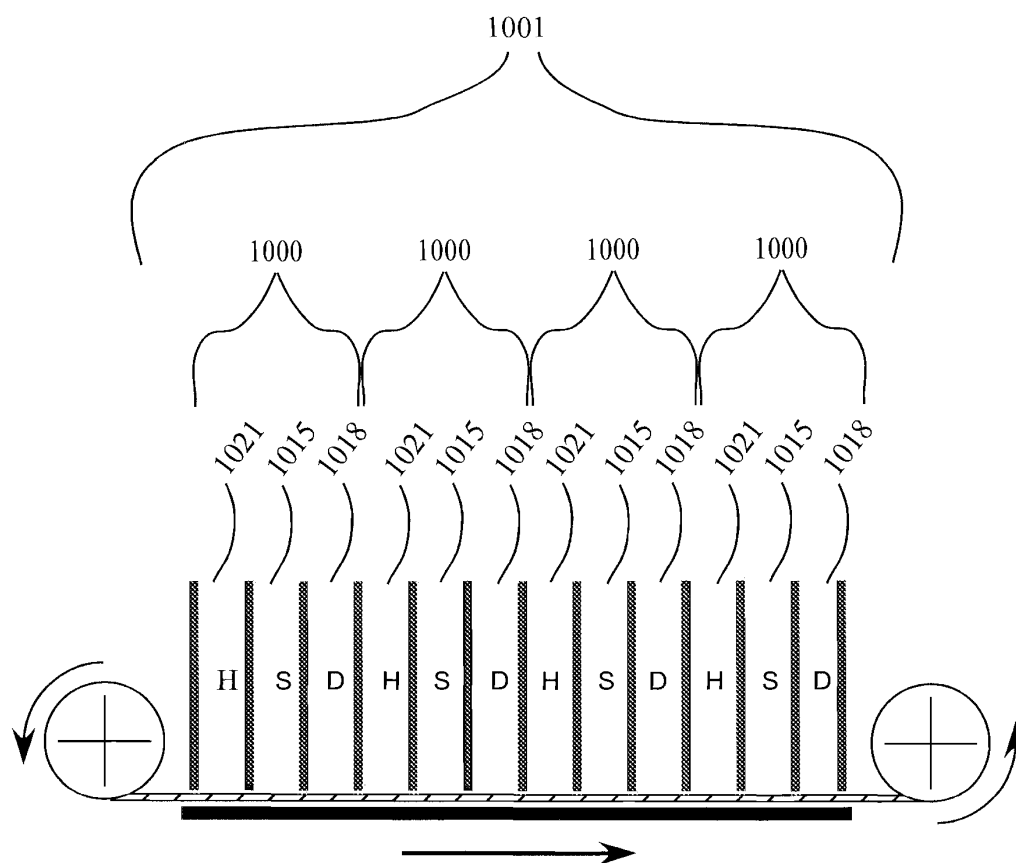


FIG 5

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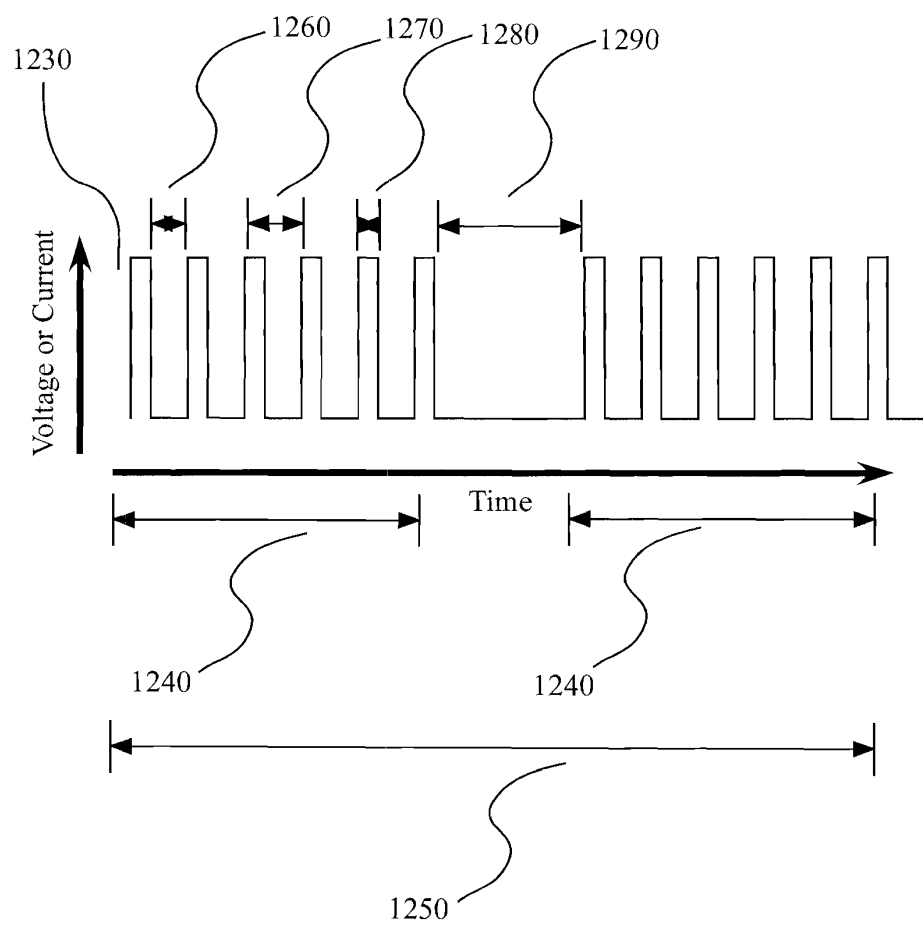


FIG 6

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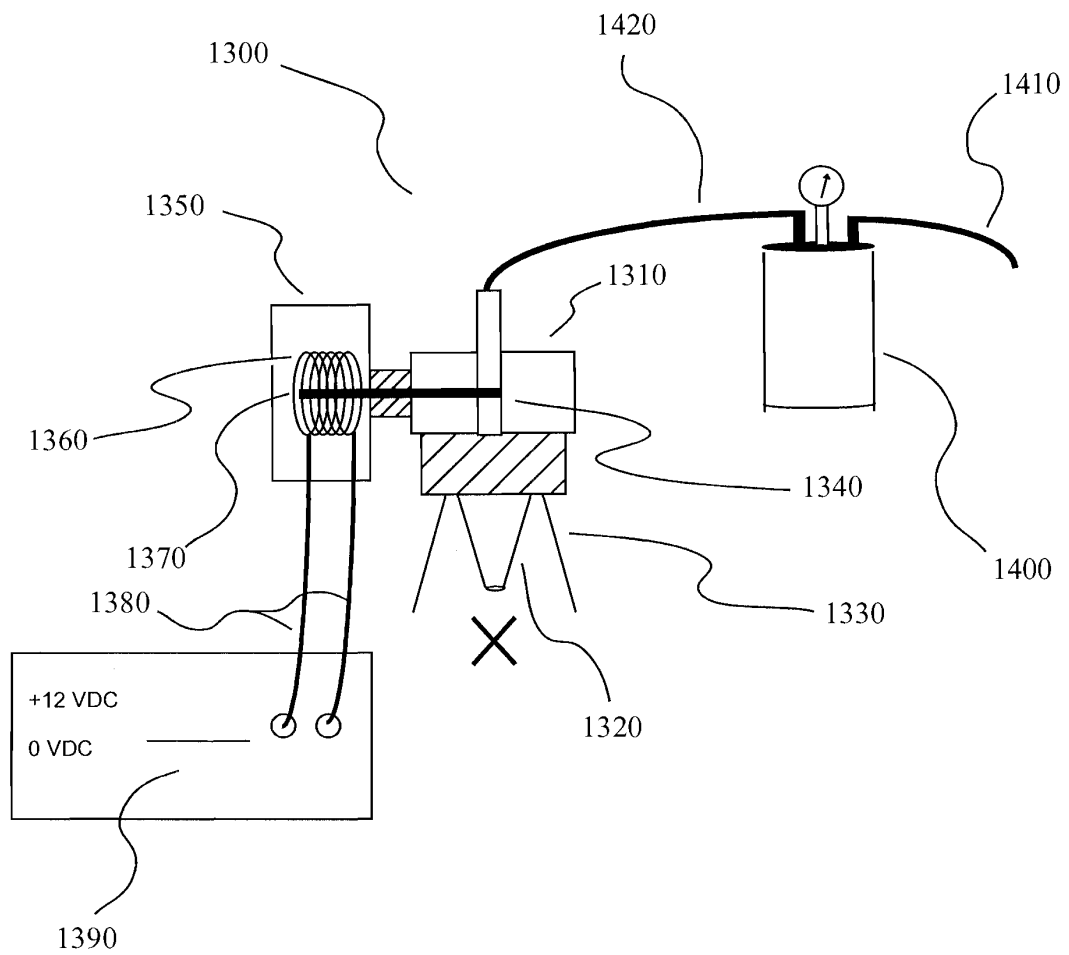


FIG 7A

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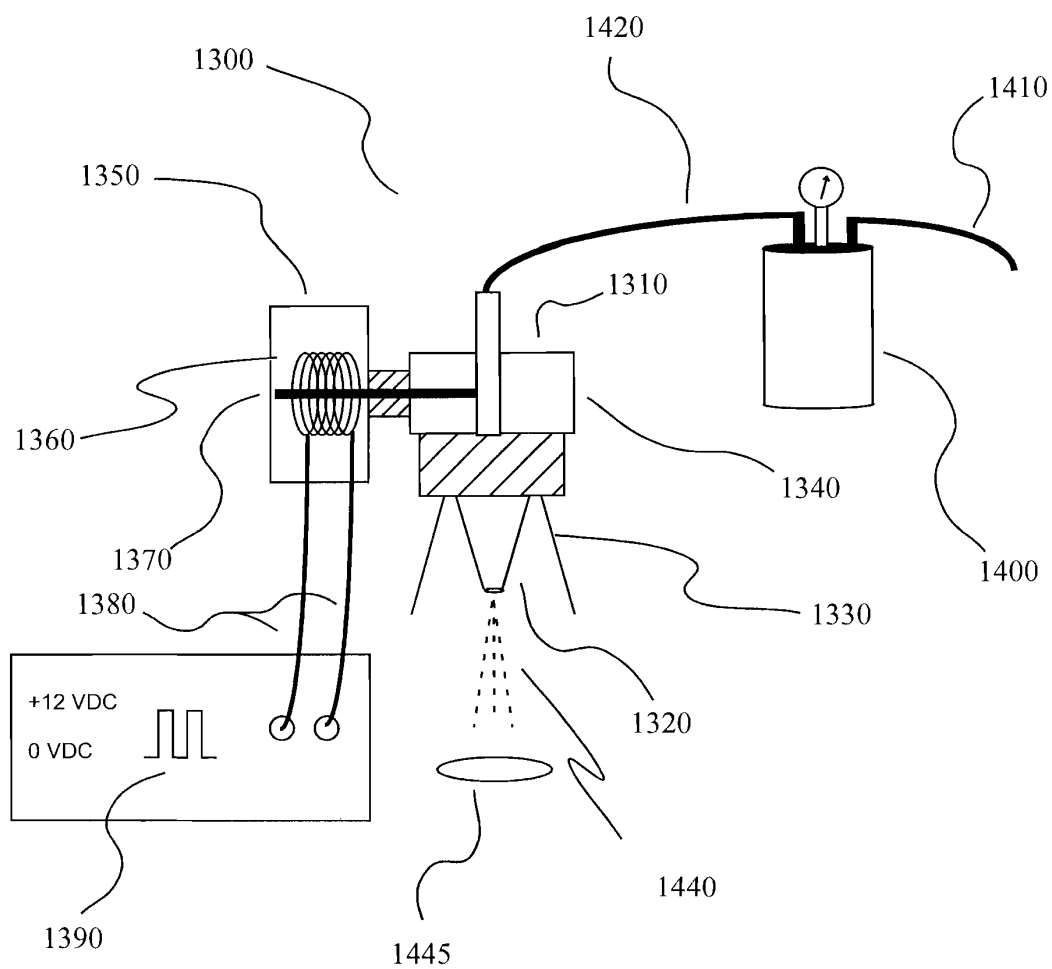


FIG 7B

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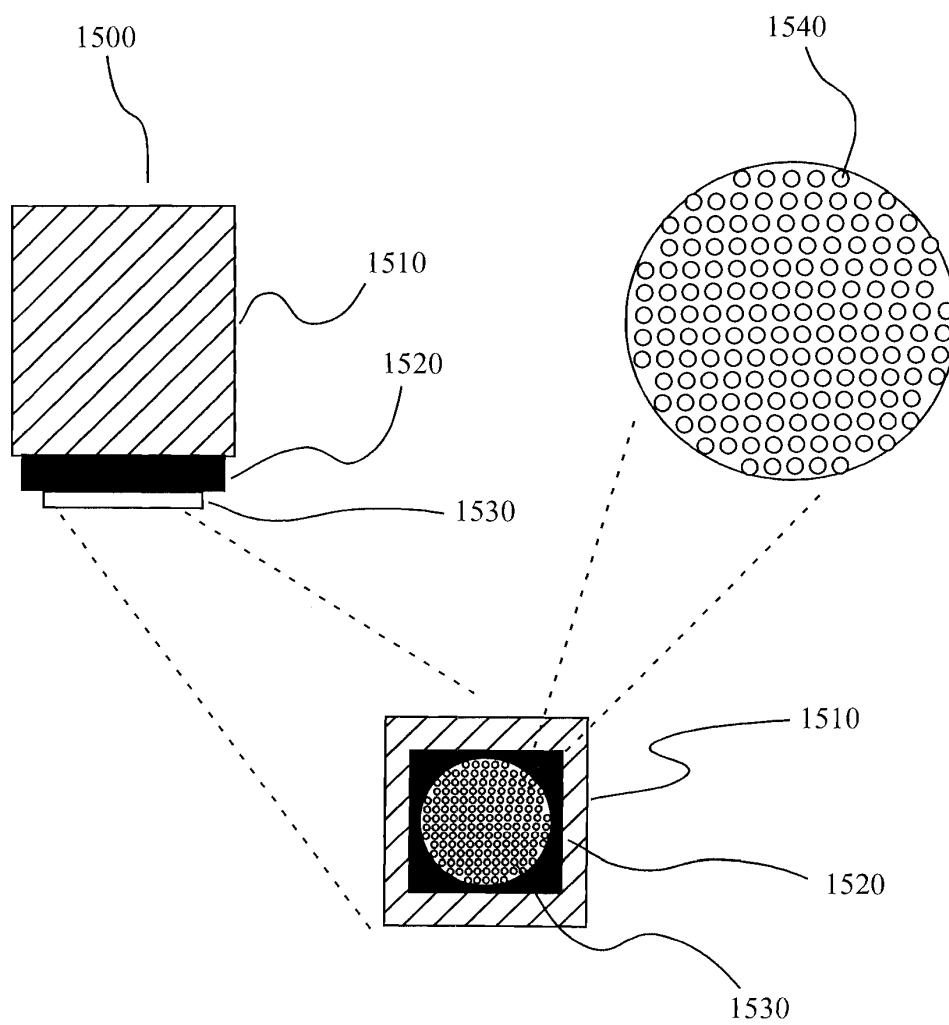
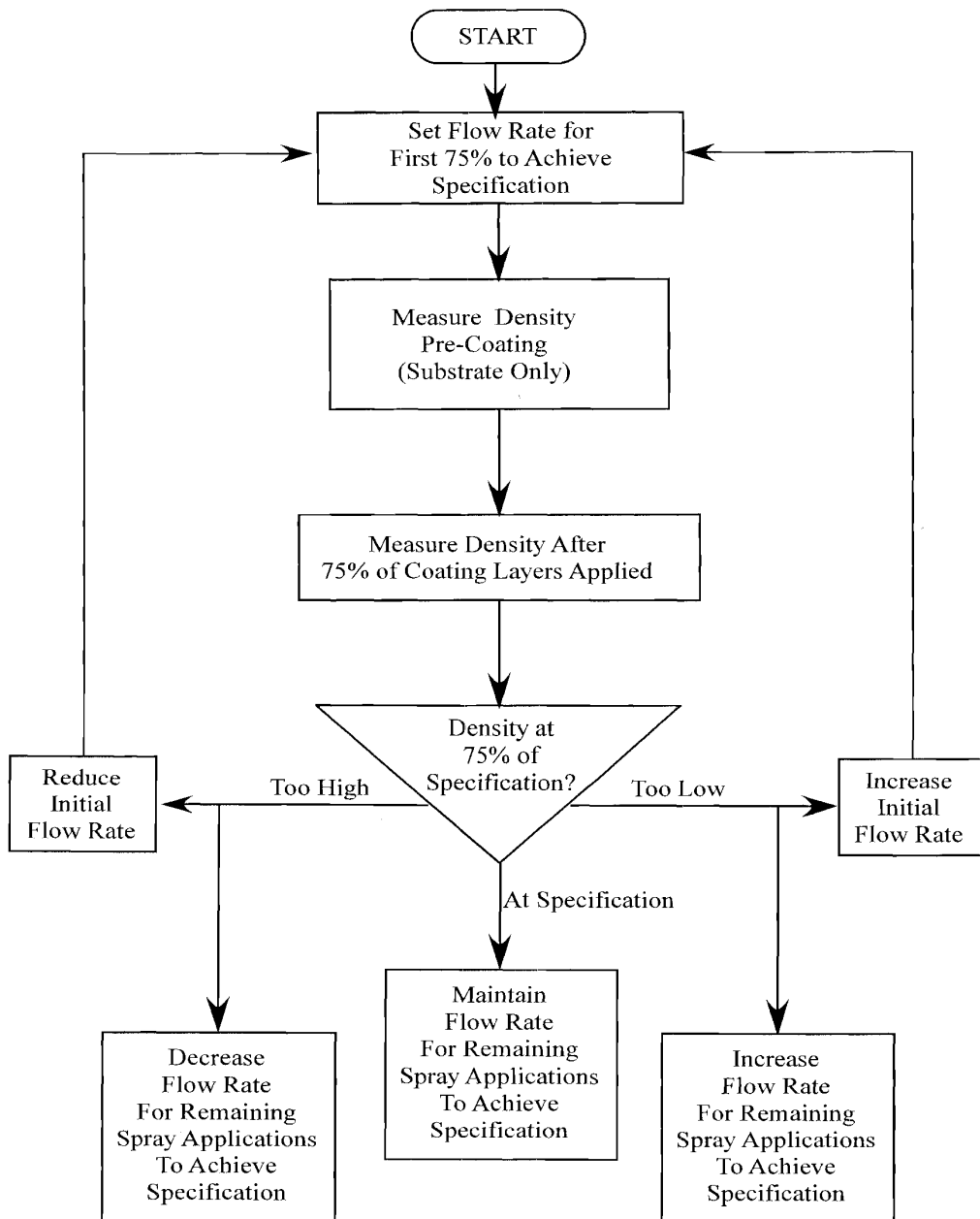


FIG 8

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**FIG 9**

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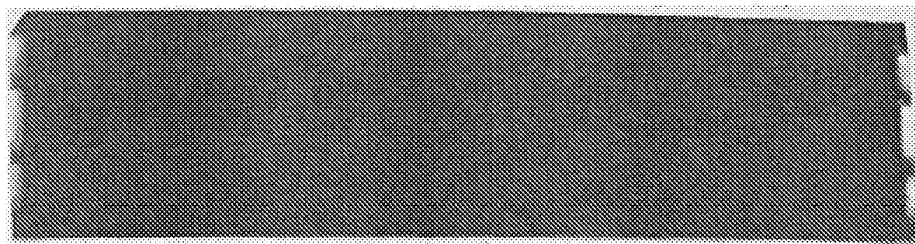


FIG 10A

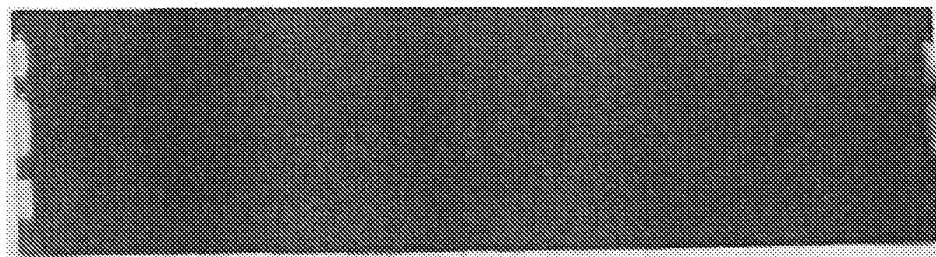


FIG 10B

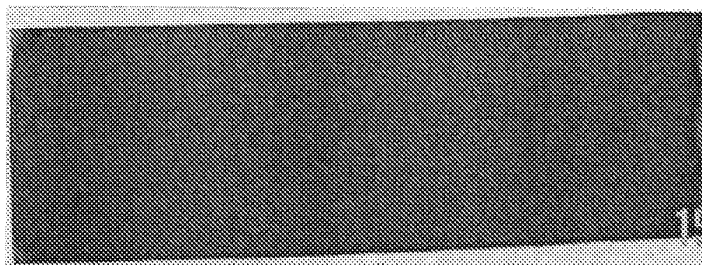


FIG 10C

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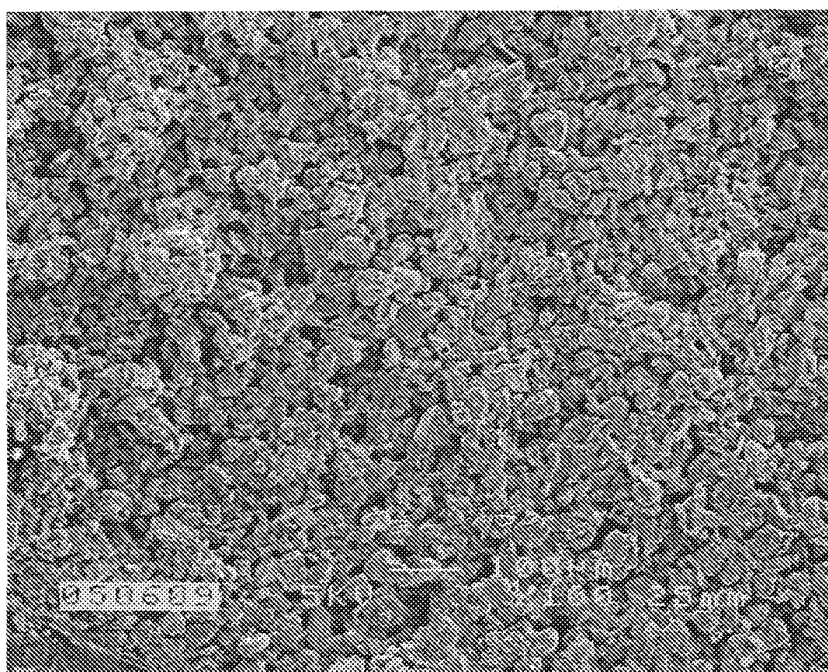


FIG 11A

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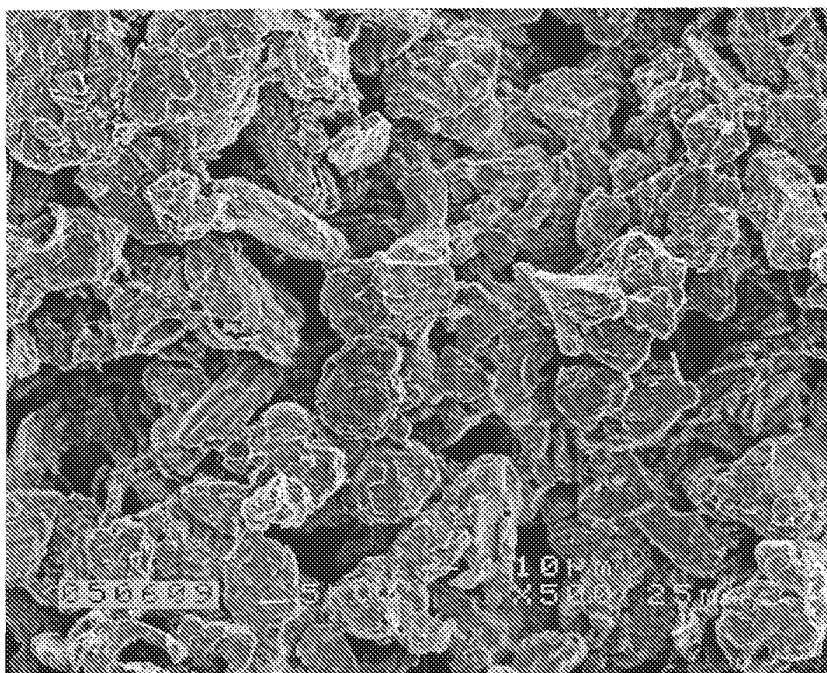


FIG 11B

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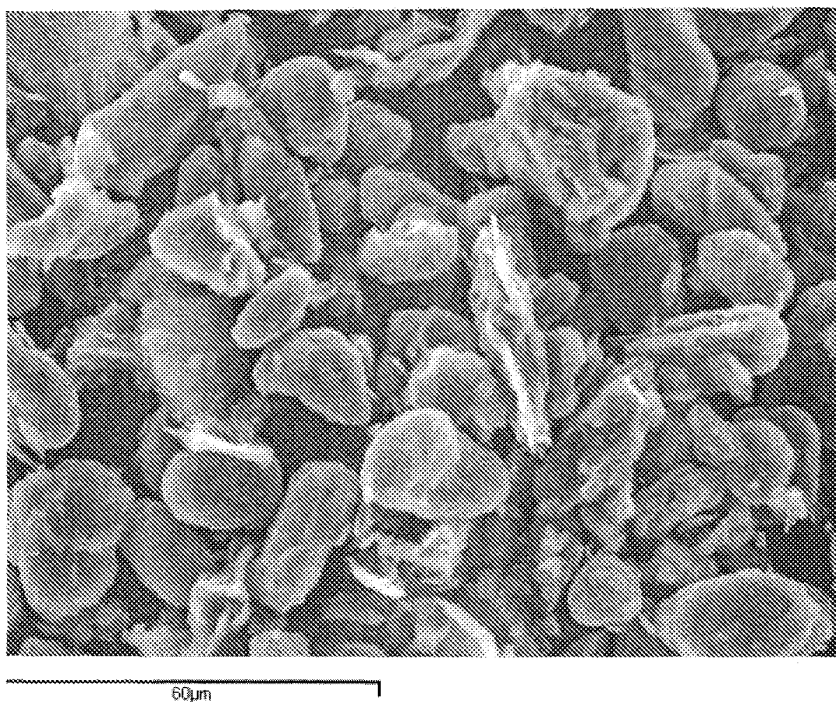
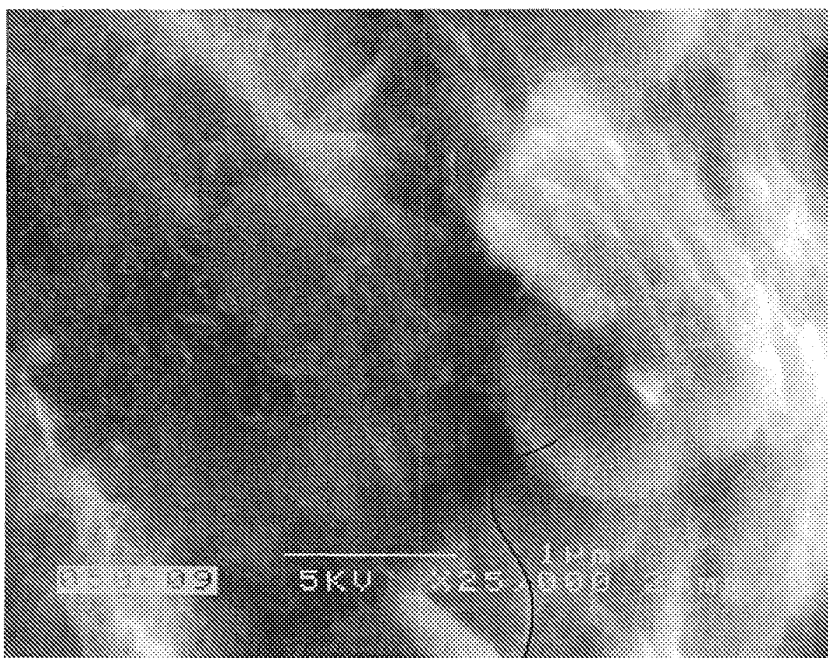


FIG 11C

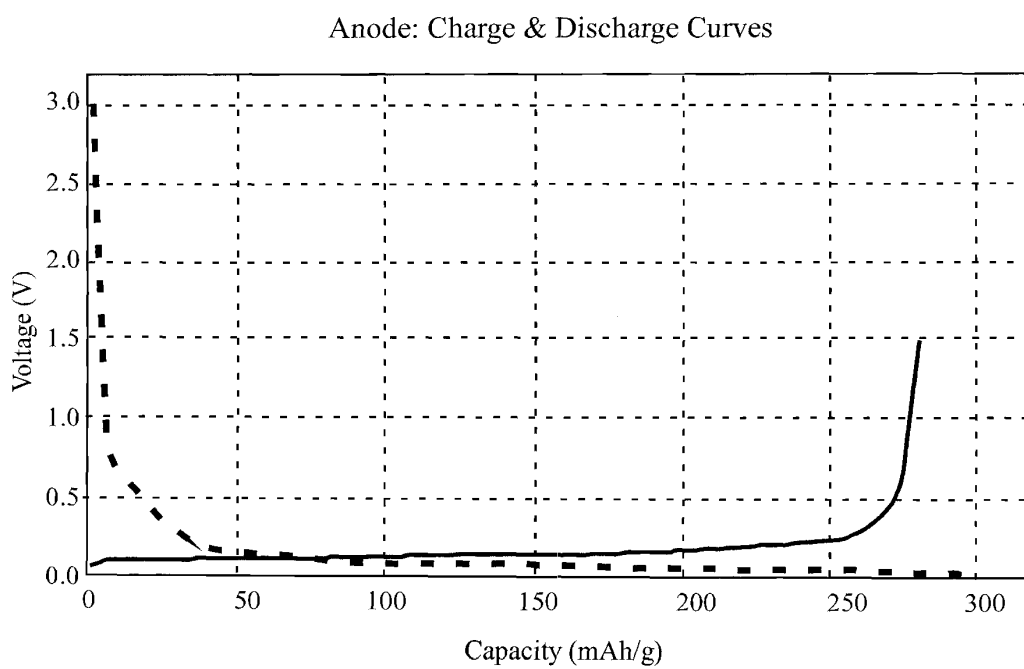
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1800

FIG 11D

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**FIG 12**

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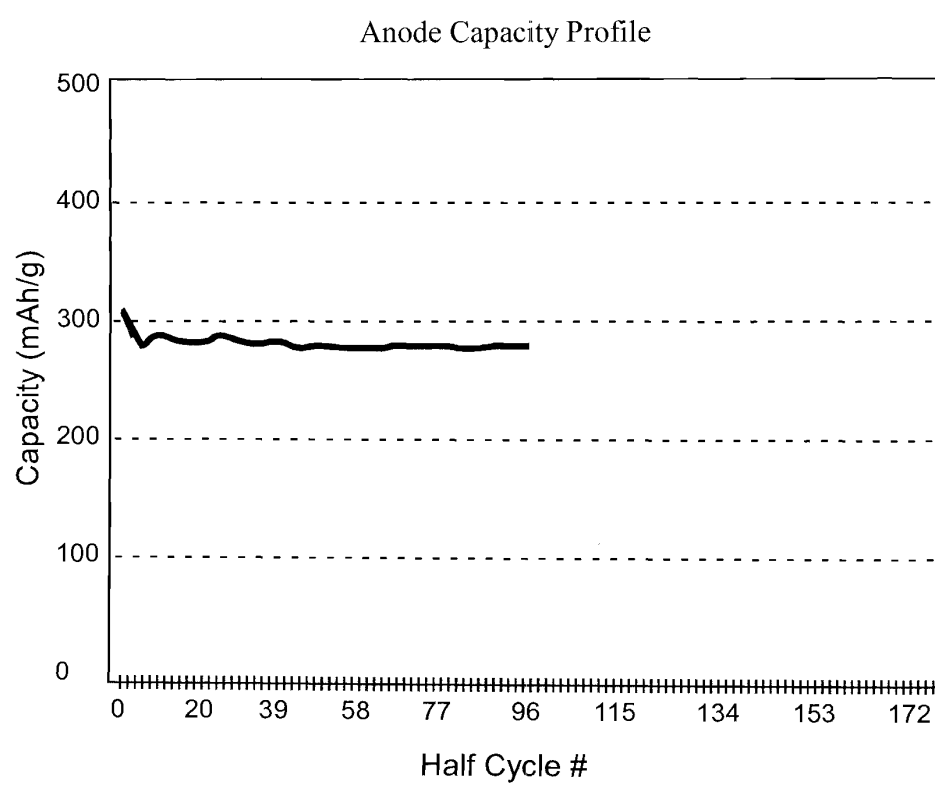


FIG 13A

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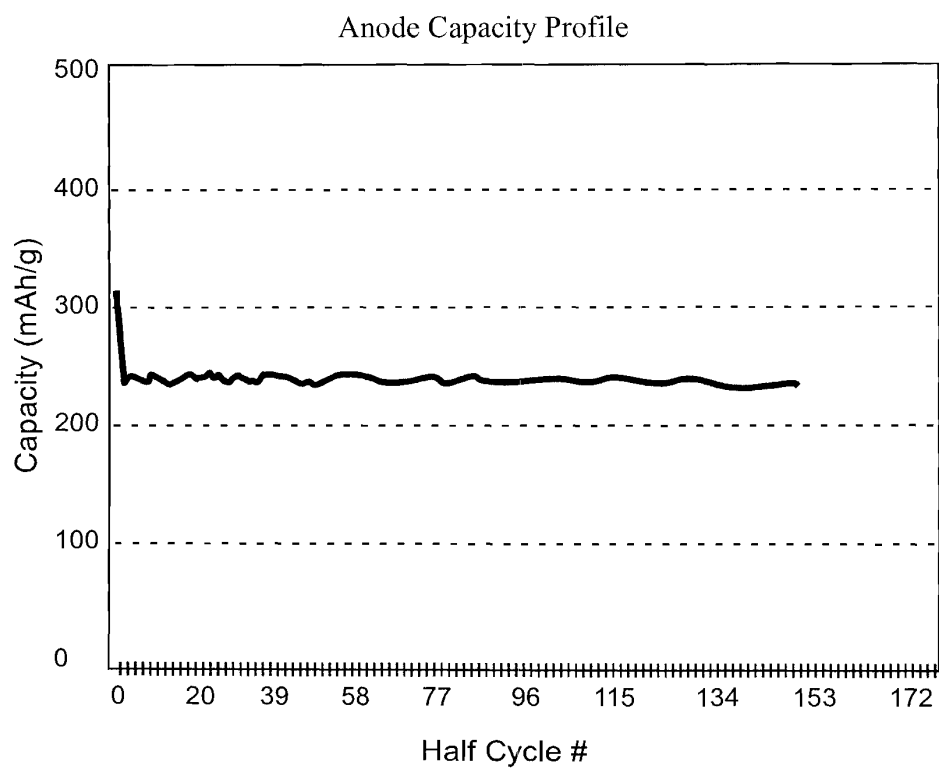
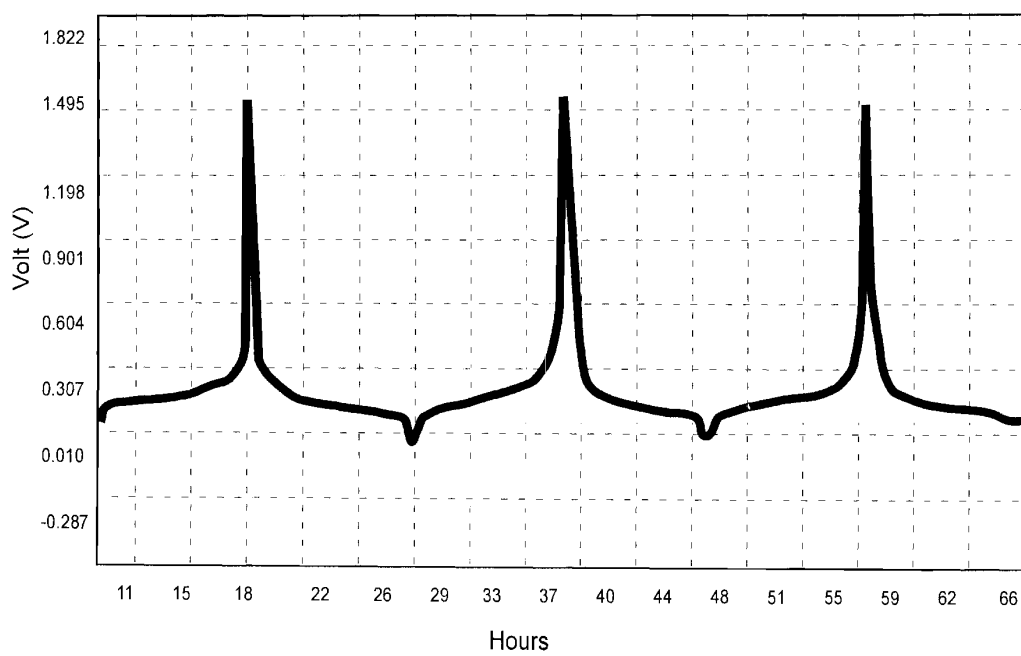


FIG 13B

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Voltage v. Time

FIG 14

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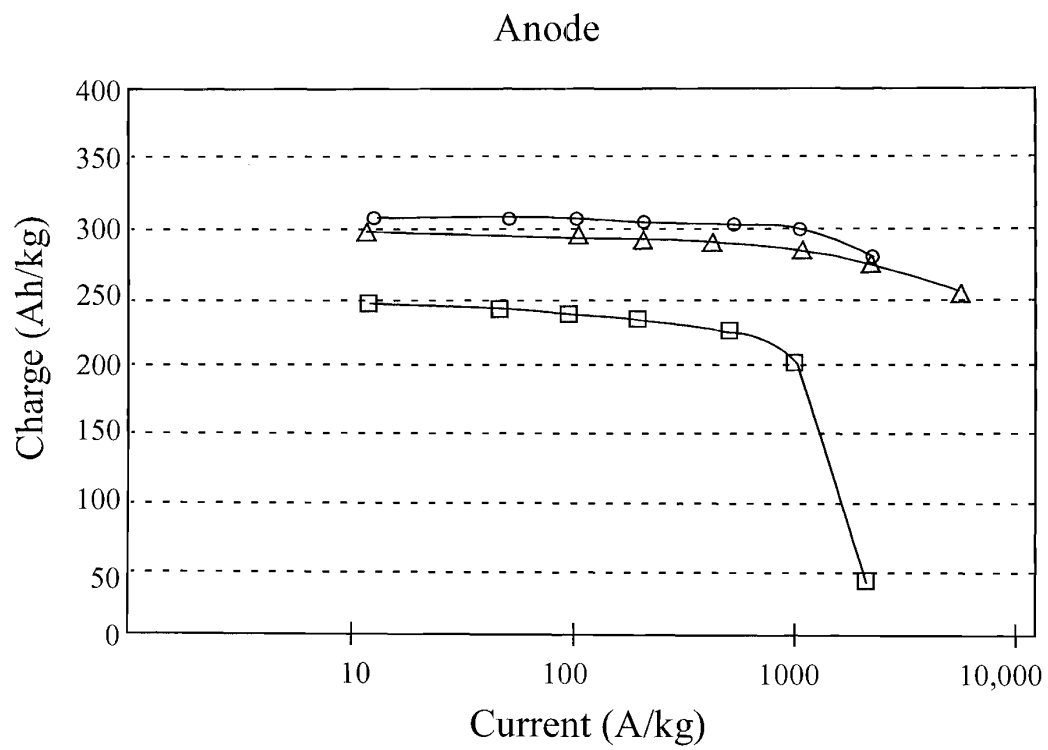


FIG 15

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Anode: Capacity v. Current

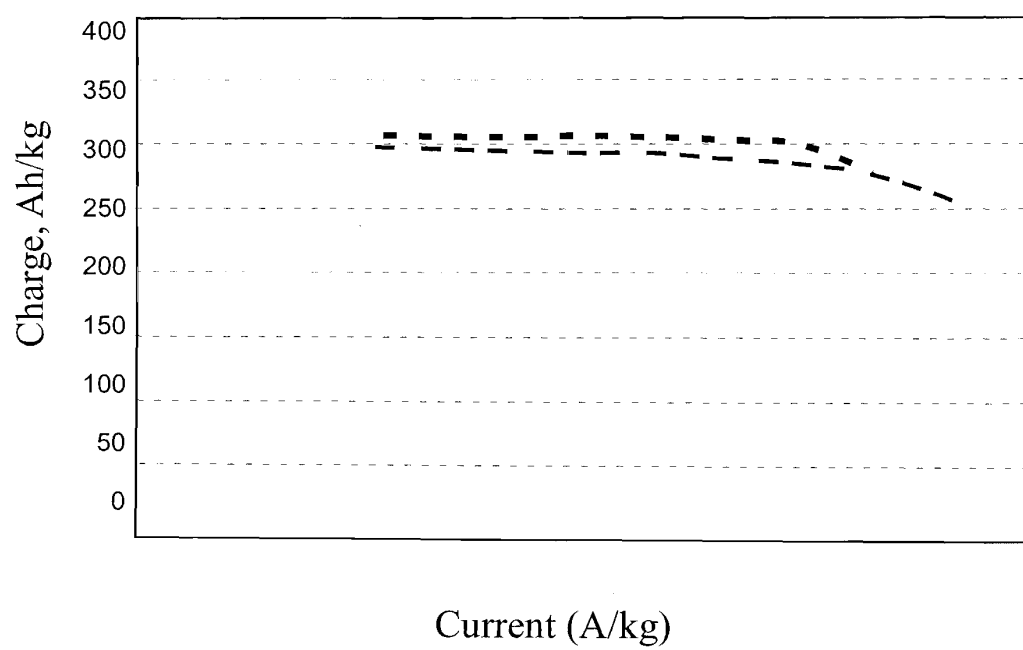


FIG 16

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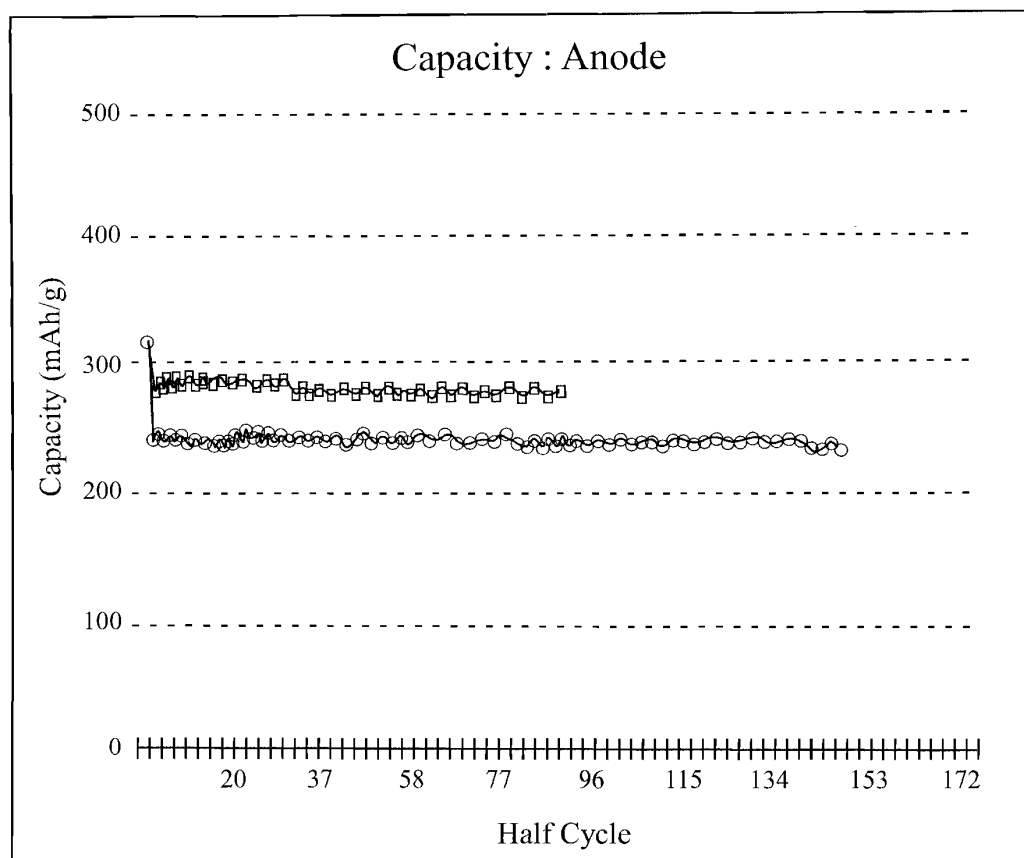


FIG 17

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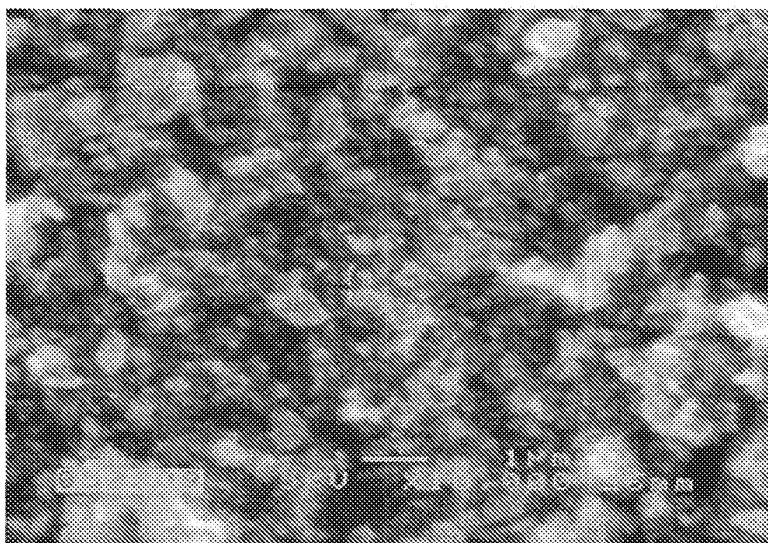


FIG 18

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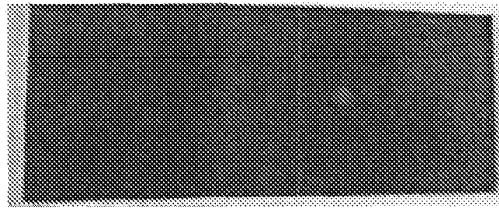


FIG 19A

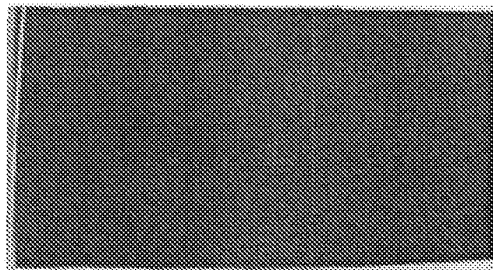
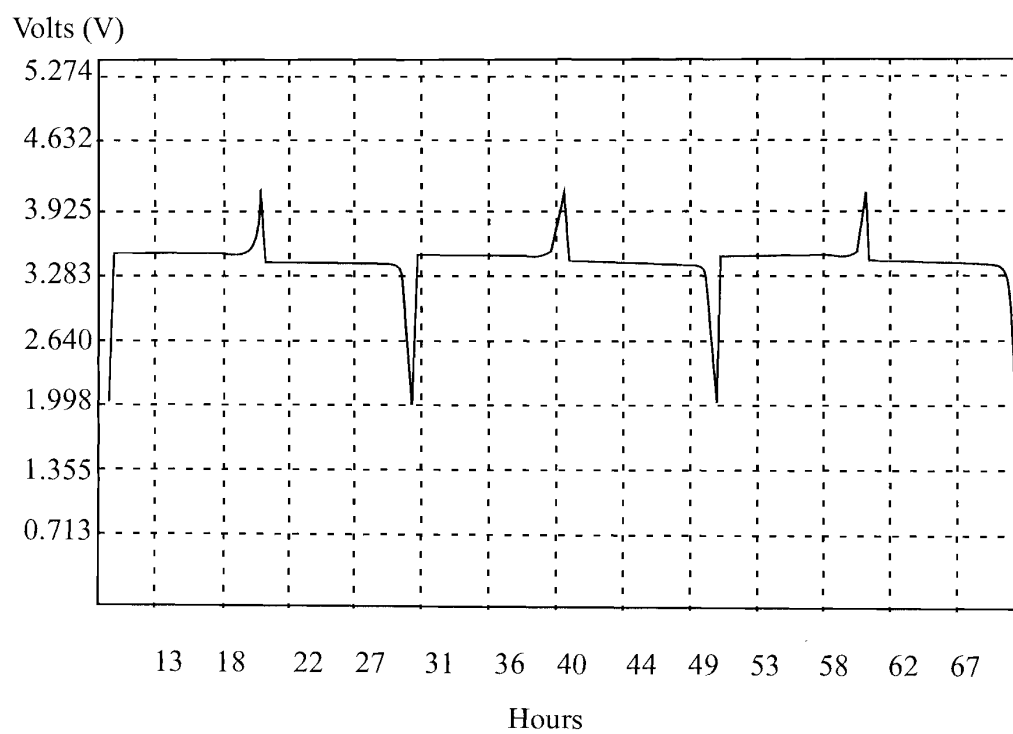
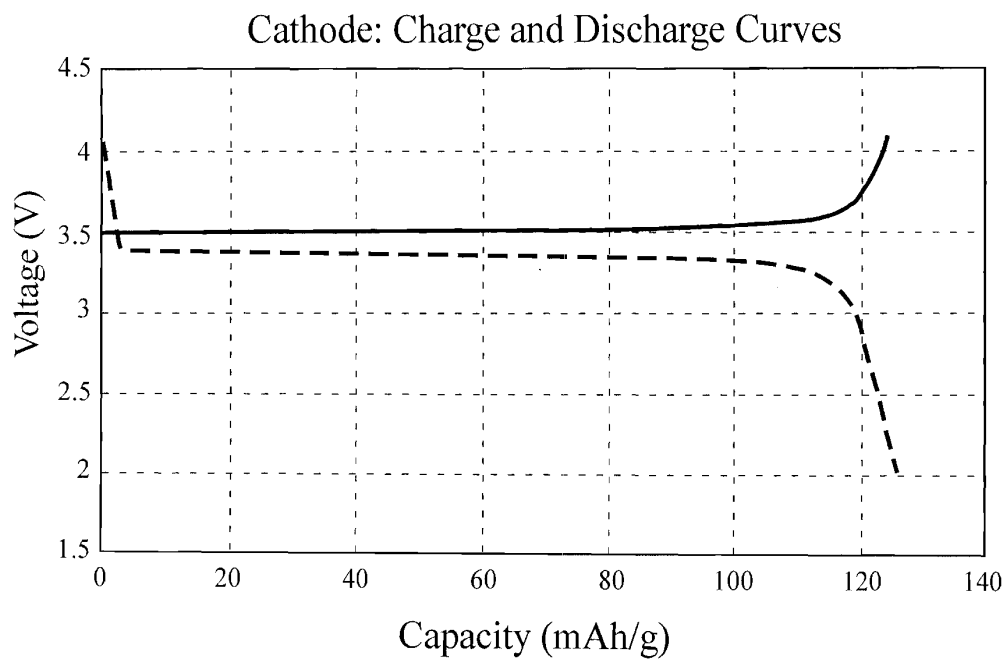


FIG 19B

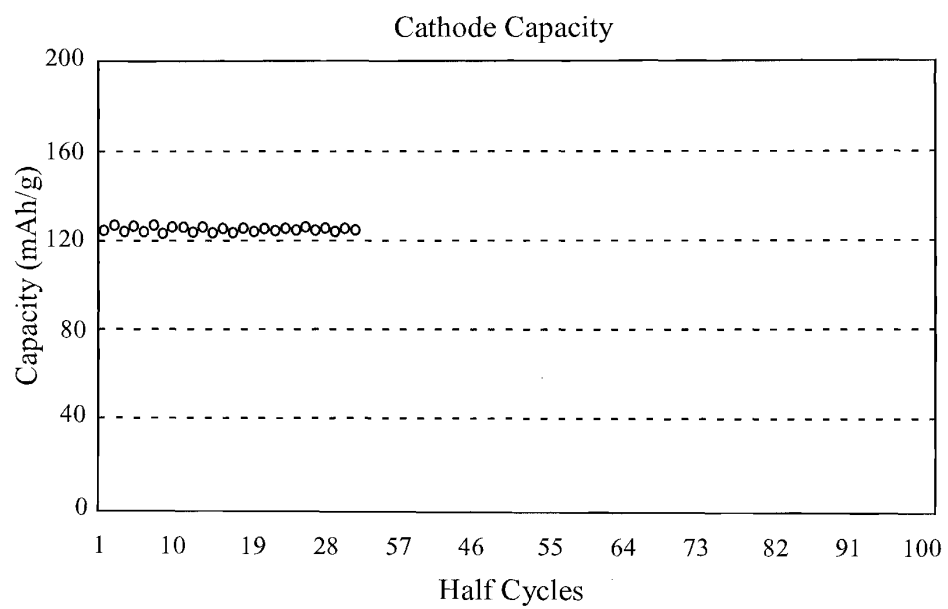
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**FIG 20**

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**FIG 21**

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**FIG 22A**

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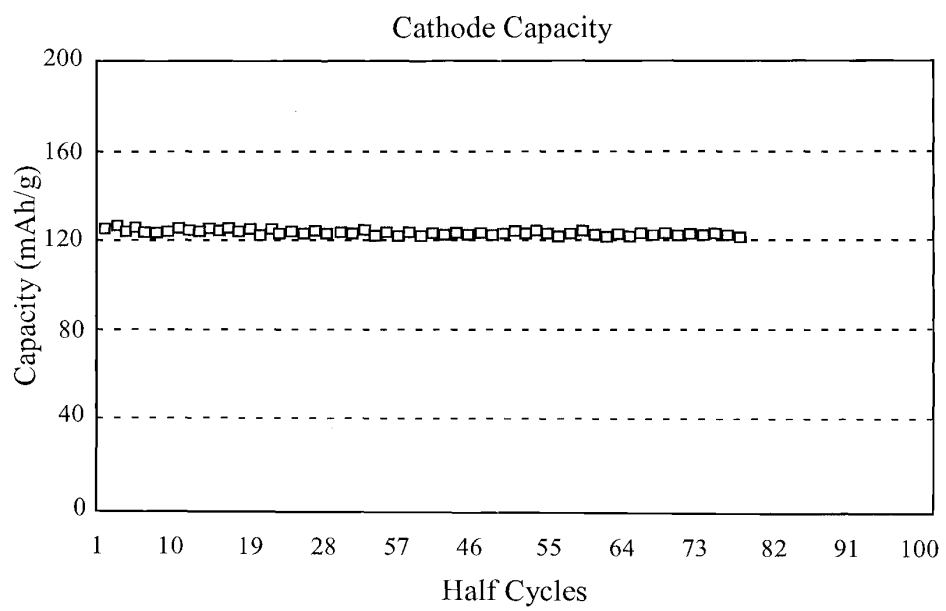
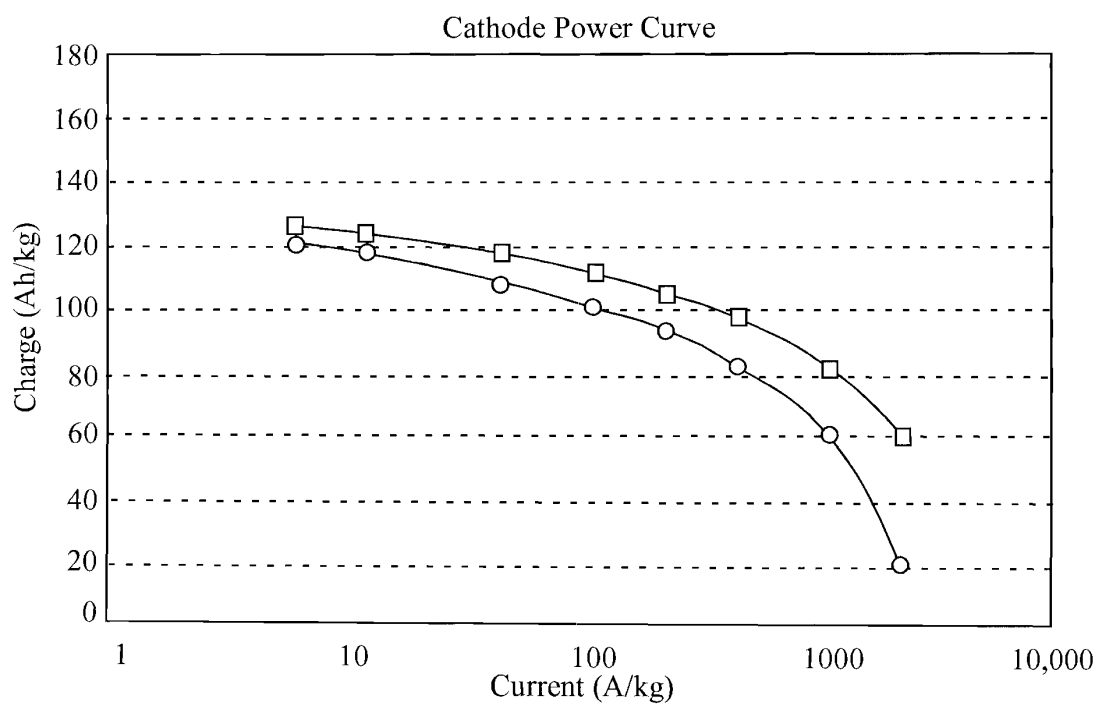


FIG 22B

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**FIG 23**

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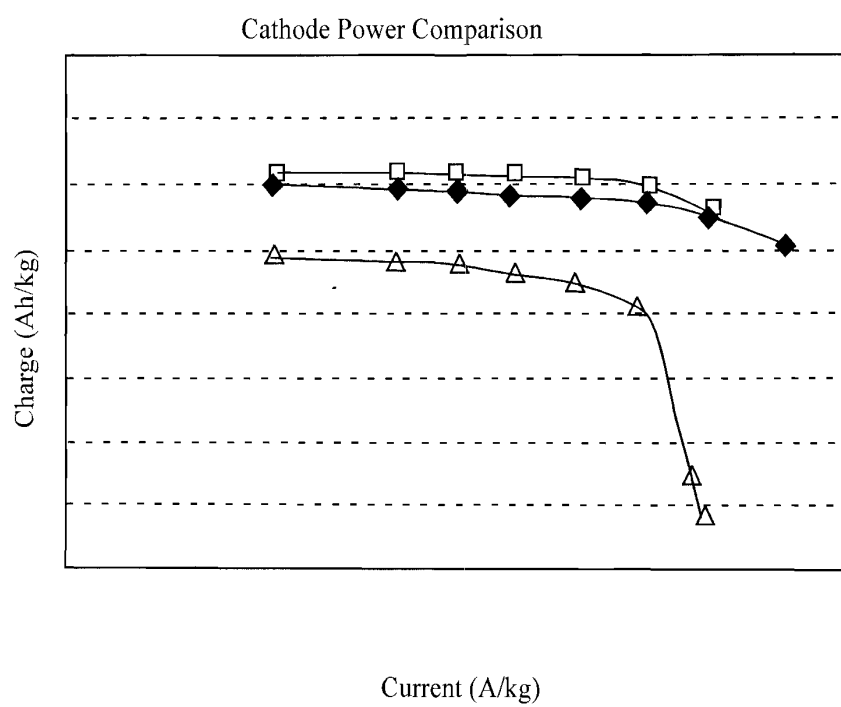


FIG 24