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(54) Title: TRUE ROLL TO ROLL IN-LINE MANUFACTURABLE LARGE AREA BATTERY AND CAPACITOR CELLS, BATTERY AND CAPACITOR STACKS

(57) Abstract: The invention relates to battery and capacitor arrangements, solutions, systems, packs, modules, and cells, materials used therein as part of the anode, cathode, separator, dielectric and/or in the manufacturing process of the battery, capacitor or any intermediate or final product, the manufacturing processes themselves and any advantageous uses enabled by the particular type of battery or capacitor obtained.



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**TRUE ROLL TO ROLL IN-LINE MANUFACTURABLE LARGE AREA BATTERY AND CAPACITOR
CELLS, BATTERY AND CAPACITOR STACKS**

Field of the invention

The invention relates to battery and capacitor arrangements, solutions, systems, packs, modules, and cells, materials used therein as part of the anode, cathode, separator, dielectric
5 and/or in the manufacturing process of the battery, capacitor or any intermediate or final product, the manufacturing processes themselves and any advantageous uses enabled by the particular type of battery or capacitor obtained.

Background of the invention

10 A variety of batteries and capacitors, in particular with respect to their internal material system, making the battery and capacitor operational. The performance of these variety of batteries and capacitors is to be judged relative to the cost of manufacturing thereof and the resulting metric determines and today actually limits also the potential uses to the presently known batteries and capacitors.

15 Today, further innovation of batteries and capacitors relies on further optimization within the paradigm of the existing manufacturing processes, characterized in that the parts of the battery and capacitor such as anode, cathode, separator and dielectric are made by separate distinct processes and assembled thereafter, which is the root cause of the cost issues described above.

The current invention is inspired by the fact that batteries and capacitors are a few orders of
20 magnitude too expensive to be economically relevant for energy storage in electricity grids or in micro-grids consisting of renewable power sources such as solar and wind power stations. Especially the capital expenditure in terms of cost per kW (power unit cost) and kWh (energy unit cost) is directly related to the complexity of the battery and capacitor cell components and with it the expensive materials and the expensive fabrication methods of coatings. The
25 fundamental reason for the complexity of the battery cell components is related to the quest for the highest energy and power density at battery cell level both in terms of volumetric as gravimetric density. For example, in Li-ion cells, the active cathode coating on the current collector is a complex compound of Lithiated oxides such as for example the Lithium Nickel Manganese Cobalt Oxide, which requires expensive and rare chemical elements such as Lithium
30 and Cobalt. Furthermore, the synthesis of solid reactants (e.g. powders) and the compounding with chemical additives to form the coating as well as the coating process need to follow

stringent protocols to obtain a specific stoichiometry of the coating and can only be applied on small conditioned surfaces given the sensitive and selective interface kinetics. Consequently, the cost of the cathode and anode almost represent over one third of the cost of a battery pack (connected battery modules and battery modules being connected battery cells). Furthermore, given the complexity of the cell components and the application of their respective coatings on small conditioned surfaces, these small battery cells are required to be tabbed, wired and assembled into modules and modules assembled into packs to attain certain energy and power ratings. The assembly cost to obtain packs is easily over 15% of the battery pack cost. Acknowledging that consumer electronics devices, portable power tools, marine, aviation, space, motive and automotive vehicles need compact and lightweight batteries, energy storage units for grids have in principle a large site footprint available and in most use cases these units remain on site. Weight is only relevant for transportation purposes where for example payloads up to 40 Ton on trucks are allowed on highways. In other words, cell density is not the primary concern of energy producers and grid operators. Their primary concern is safety and cost effectiveness of the energy storage units and the battery cell is a large unit cost adder over 50% of the unit cost of a battery pack in terms of bill-of-materials, the processing of the coatings and all assembly steps involved. Apart from being biased towards high density battery cells research and development around the world is locked into small battery cell making compatible with module and pack assembly that is globally established. Historically, small battery cells were made on narrow magnetic tape machinery back in the nineties. Sony was under pressure to find an alternative application for the tools as magnetic tapes were displaced by compact discs. Acknowledging that the battery cells were aimed for consumer electronic devices such as cell phones, further research and development continued aiming for small form factor battery cells whereby multiple battery cells were assembled in modules for use in portable power tools and larger consumer electronics devices. This bias continued with the assembly of larger modules and even the assembly of multiple modules into packs to address larger power and energy ratings for use in the marine, aviation, space, motive and automotive sectors. Although this approach provides modularity, the minimum scale requirements (or smallest unit) in the energy sector are an order of magnitude larger than the largest battery backed vehicle that could be imagined. With this polarization towards module and pack assembly, innovations around classical (rocking chair single ion e.g. sodium) battery types all tend to be compatible not only with the cell manufacturing methods of Li-ion cells, but also with the long and well established footprint of module and pack assembly factories around the globe.

Aim of the invention

It is the aim of the invention to solve the above issue by starting from an entirely different manufacturing paradigm.

Summary of the invention

- 5 It is a first aspect of the invention to provide a manufacturing method for a battery and capacitor cell by for at least two parts of said battery and capacitor cell use foil or sheet based manufacturing, and thereafter combining both generated parts in a further foil or sheet based manner.

- 10 It is a second aspect of the invention to provide, in the spirit of the first aspect of the invention, suitable foil or sheet based manufacturing of one or more of said parts, more in particular methods of manufacturing benefiting of such selected foil or sheet based method, in particular by either combining the manufacturing of such parts (such as anode or cathode with the separator) and/or starting from easier (providable in roll format) materials for such anode or cathode (compared to more difficult to process material stacks resulting from further optimizing
15 the prior-art methods of manufacturing).

In an embodiment of the invention extrusion coating processes are used for manufacturing of the separator, dielectric and/or the protecting part of the anode or cathode.

In an embodiment of the invention roll-to-roll aerosol processes such as graphene deposition from CO₂ are used for manufacturing of the protecting part of the anode or cathode.

- 20 In a further particular embodiment of the invention use of a foamed polymer or foamed polymer compound is provided.

- In another embodiment of the invention use of a polymer with embedded metallic materials is provided for the protective layer or current collector of the anode, cathode or both. Also in an embodiment of the invention use of a polymer with embedded dielectric materials is provided
25 for the dielectric in a capacitor cell.

In an embodiment of the invention coating processes are used for manufacturing of the anode or cathode, of which hence one of those or both become at least two layered.

It is worth emphasizing already at this stage, that when operating in the above outlined (combined) (in-line) roll-based approach, that also other processes (such as the providing of

conductors for connecting purposes or insulators for cooling purposes while finishing the battery module or pack) can (and preferably are) embedded therein.

It is also worth noting that when operating in the above outlined (combined) (in-line) roll-based approach alternative methods for customisation of battery cells, modules and packs during
5 manufacturing can be used, in particular in varying the materials used in the extrusion coating and/or other for in-line suitable coating processes and/or the processing parameters of one or more of these steps.

For sake of completeness the above battery and capacitor (part) manufacturing method which will include at least one outlined foil or sheet-based manufacturing approach may be combined
10 with off-line or discontinuous processes also.

Brief description of the drawings

Figure 1 shows schematically a battery or capacitor (10) with its anode (20), its cathode, its separator or dielectric (40) and its electrolyte (50).

15 Figure 2 show two embodiments of a foil or sheet-based manufacturing of a combined layer (120) being the current collector or capacitor plate (100), provided from a roll, with the separator or dielectric (110), provided thereon via an extrusion coating process (210).

Figure 3 shows an embodiment of a foil or sheet-based manufacturing of the anode or cathode via a coating step (300) followed with the embodiment of Figure 2 (top). Alternative to the
20 embodiment of Figure 2 (bottom) could be combined therewith also. A further alternative to the embodiment of Figure 2 (top) could be combined with a capacitor plate (100), provided from a roll, provided thereon via a calendaring process or an assembly or stacking step.

Figure 4 shows schematically a battery (10) with its anode (20), its cathode, its separator (40) and its electrolyte (50), manufacturable in accordance with the method of Figure 3, more in
25 particular the anode (or cathode) comprises now two layers (100, 130) of which one is provided as a foil or sheet via a roll while the other is provided via an in-line continuous coating process. For sake of completeness the coating steps (420, 300) can comprise of none or one or more coating steps.

Figure 5 shows an embodiment of the invention in accordance with the first aspect of the
30 invention in that combinations of roll-based processes are used. Note hybrid combinations of

at least one continuous in-line roll-based with multiple other in-line or off-line roll- or sheet based processes are also possible.

Figure 6 shows schematically a battery (10) with its anode (20), its cathode, its separator (40) and its electrolyte (50), manufacturable in accordance with the method of Figure 5, more in particular both the anode and cathode comprises now two layers (100, 130 and 410, 430 respectively) of which one is provided as a foil or sheet via a roll while the other is provided via an in-line continuous coating process.

Figure 7 shows an embodiment of a foil or sheet-based manufacturing of the anode or cathode via a providing of a protective layer with a coating process, based on extrusion coating, liquid or aerosol coating, vapor deposition based, atomic layer deposition based and/or epitaxial growth (500) further another similar coating step (300) discussed before and further followed with the embodiment of Figure 2 (top). Alternative the embodiment of Figure 2 (bottom) could be combined therewith also.

Figure 8 shows an embodiment wherein the (layered) foil (460) produced by any of the foil or sheet- based manufacturing methods is also provided on a roll (possibly at a place distant from its original production placed), further extra steps (1000) are applied like tabbing with conductive layers for wiring purposes and coating with insulating layers for heat sinking purposes (preferably at the outer edges of the (AL) foil (all around)) then cut at a desired length and thereafter a further processing step (such as for providing electrical and thermal conductors).

Figure 9 shows a large area cell manufacturing method based on bending or rolling the foil.

Figure 10 shows an alternative module manufacturing method based on repetitive execution of the above outlined processes.

Figure 11 shows an exemplary module in accordance with the method of Figure 10.

Figure 12 shows two embodiments of modules in accordance with the module manufacturing methods described, one embodiment with isolation (for instance paper or plastics based) between the cells (left) and one advantageous embodiment with conduction (for instance Al based) between the cells (right).

Figure 13 provides a manufacturing method with a protection and active layer on one side of the foil while the separator being provided on the other side of the foil. A similar approach can

be used for a capacitor by instead of the separator providing a dielectric layer with the extrusion (or alternatively tape casting).

Figure 14 is an example of a stack with common current collectors for subsequent cells in a battery stack.

- 5 Figure 15 illustrates a stack provided with heat exchange elements.

Detailed description of the invention

With specific reference now to the figures, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the different embodiments of the present invention only. They are presented in the cause of providing what is believed to be the
10 most useful and readily description of the principles and conceptual aspects of the invention. In this regard no attempt is made to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention. The description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

- 15 The invention relates to batteries and capacitors. While in batteries a separator and current collector are used, in capacitors a dielectric and capacitor plate are used instead.

The invention inspired by the need of a paradigm to cut the cost of batteries and capacitors drastically is related to a battery and capacitor (electrolyte neutral or agnostic) cell architecture and processing that allows to produce cells with mass volume production methods from totally
20 unrelated industries and upon which the multiplication of production capacity can happen very fast and on a global scale. With a high multiplication factor, cost learning curves and related price erosions rippling through the value chain from material to battery and capacitor system production will be unprecedented and is the only sustainable strategy to preempt current state-of-the art cost ineffective Li-ion batteries and super capacitors for stationary energy storage. In
25 the search for a novel cell architecture, in particular for batteries, it is important to pursue a battery cell type that allows to keep the cathode and anode as simple as possible, avoiding complexes, alloys or multi-layer structures and where both cell components can be produced with cheap well established production methods, preferably capable to implement battery cell types like the dual ion non-rocking chair cell where charge storage within the cell occurs at both
30 sides at anode and cathode. Then both working ions should be hosted by the electrolyte in between both cell components and charge storage at both sides of the cell may occur via

plate/strip, alloying/dealloying or graphite intercalation. Therefore, the electrode can be a bulk single atomic element metal substrate for certain ions migrating out of the electrolyte or a conventional graphite electrode for other ions. When a bulk single atomic element metal substrate is effective for ion charge storage it suddenly also serves as current collector to allow electronic charge transport outside the battery cell. In Li-ion cells each electrode has a separate substrate for the current collection next to an active layer for ion charge storage (both a graphite layer at the anode side and a complex alloy at the cathode side). When a graphite layer is needed for ion charge storage, then a separate substrate for current collection is required.

Figure 2 (top) shows a first embodiment the extruder is provided with granulates (240) and foaming agents (250). Figure 2 (bottom) shows a second alternative embodiment wherein a further (IR) radiation step (220) is used to start or further enhance the foaming process. Finally, a step of cutting (260) of the resulting composite layer is performed directly or after additional (preferably also roll or sheet based manufacturing layers are combined thereto as shown in Figure 5). As such Figure 2 top shows a first manufacturing process with a support (100) (deployed from a roll (200)) on which via an extruder (210) directly said foamed polymer or dielectric (110) is provided. The support (100) is selected to be suitable as current collector and for roll processes for subsequent inline coating of other required battery or capacitor cell elements. After this step the resulting stack can be cut (possible after further steps are performed on it). Figure 2 bottom shows a second (alternative) manufacturing process with a support (100) (deployed from a roll (200)) on which via an extruder (210) provides polymer (110) and via (IR) radiation foaming occurs.

Figure 5 shows an embodiment of the invention in accordance with the first aspect of the invention in that combinations of roll based processes are used, in particular the anode (or cathode) is made with the processes left of Figure 3, further on one of those the separator or dielectric is provided (with any of the embodiments of Figure 3) and finally combined (450) and cut (260). Figure 5 hence shows a combined manufacturing process wherein layers or supports are provided with coatings, further one thereof is provided with a separator and thereafter the entire stack is combined before cutting.

For sake of clarity, in the suggested combined flow as shown in Figure 5 preferably the speeds of the rolls are adjusted to each other as schematically indicated by the dashed roll. Further the

suggested combined flow here also entirely a schematic representation and not a concrete outline of the manufacturing facility. It should be clear for instance that the combining step requires a turning of the obtained foil (440), e.g. by use of an additional roll element (not shown).

- 5 Figure 7 shows an alternative process, wherein the protective layer is also provided via an extruder (500). Figure 7 shows hence an embodiment of a foil or sheet based manufacturing of the anode or cathode via a providing of a protective layer with a coating process (500) further another coating step for the active layer (300) discussed before and further followed with the embodiment of Figure 2 (top). Alternative the embodiment of Figure 2 (bottom) could be
10 combined therewith also. Also here an extruder (500) is provided with granulates (510) and agents (520). Note that the anode and cathode made in accordance with this process comprises now four layers respectively current collector, protective layer, active layer and separator (not shown explicitly in the drawings).

As the purpose is to provide a battery or capacitor (or at least materials suitable for forming
15 one) implicitly the selected or resulting materials are characterized in that the ion transport for the electro-chemistry system defined by the anode, cathode and electrolyte or the electron storage at anode and cathode must be operable. In particular the separator and the electrolyte which is substantially being provided inside part of said separator context is specifically designed therefore. Likewise, the dielectric elements being provided inside part of said
20 dielectric context is specifically designed therefore.

A variety of embodiments are now described:

- (1) In one embodiment a truly roll-to-roll process to generate an aluminum chloride-graphite battery is described. In order to produce this type of battery cell structure an aluminum -foil is used as an anode material or current collector. This aluminum foil is
25 unrolled and is subsequently extrusion coated with an open-cell polymer foam, which is for example produced using CO₂ or N₂ as a physical blowing agent. The foam coating thickness is controlled by calendaring rolls. The extrusion coated polymer coating is acting as separator and can be formulated with an adhesion additive to allow for proper adhesion to the anode or current collector surface. Next to this, also a thermal or light-
30 induced cross-linking of the polymer can be applied to improve the thermal and/or chemical resistance of the foam. The described structure is an anode or current

- collector foil with an in-line coated separator. In a separate step the cathode is prepared by coating a protective layer on a current collector via an in-line physical vapor deposition process. An example is a coating of TiN on an Aluminum foil. This double layered foil is subsequently coated on the earlier coated side with a graphite slurry. The anode part (Aluminum and) and the cathode part (current collector – protective layer - graphite) with in between the separator are together cut to the proper length, which depends on the desired capacity or energy rating of the battery or capacitor cell. Tabs for electrical wiring and insulating layers for heat sinking are coated on anode and cathode foils at appropriate places. A stack of alternating anode and cathode foils is formed and inserted in or coated again using the inline roll processes to form a packaging enclosure where an AlCl_3 -EMIMCl (1-methyl-3-ethylimidazolium chloride) anolyte is added to the packaging to form the battery cell, module or pack.
- (2) In a second embodiment cathode and anode are produced in the same roll-to-roll process but the way of producing the separator foam is slightly different, where a chemical blowing agent is used instead of a physical blowing agent. The chemical blowing agent is added to the extruder and at a given polymer melt temperature the chemical foaming agent is decomposing and forming an inert gas (such as CO_2 or N_2), resulting in an open-cell structured foam at the exit sheet- or foil die.
- (3) In a third embodiment a similar process can be imagined where the unrolled Aluminum foil is coated via extrusion coating with a polymer that contains a chemical blowing agent. The thickness of the coating is controlled by calendaring rolls. The extrusion coating is performed at a temperature that is lower than the decomposition temperature of the chemical blowing agent. If a proper thickness is achieved, the assembly is passing through an in-line oven with a temperature that is higher than the decomposition temperature of the chemical foaming agent. During this secondary heating step, the open-cell structure in the polymer coating is formed. An additional cross-linking agent can be added to the polymer melt that will simultaneously start to cross-link the polymer during the formation of the open cell structure to prevent the foam from collapsing. The rest of the battery pack or module is produced in the same way as described above.
- (4) In a fourth embodiment the foamed open cell separator is not formed using an extrusion coating, but via a chemical polymerization reaction. Here, two liquids are mixed and coated on the Aluminum substrate, where a chemical reaction is taking

place. An example can be the reaction of an isocyanate liquid and a diol with hydroxyl groups. In combination with a catalyst an open-cell polyurethane foam can be formed on the Aluminum substrate, resulting in an anode with in-line produced foamed polymer separator.

- 5 (5) In a fifth embodiment the in-line polymer foam can be produced on the cathode side. In this case, an Aluminum substrate is coated with a protective coating (for example TiN coating via physical vapor deposition). This assembly is then slurry-coated with a graphite slurry. After calendaring and drying the foamed polymer can be coated on top of the graphite surface using either the earlier described extrusion coating via physical or chemical foaming techniques. This assembly is then combined with an unrolled Aluminum foil and this assembly is cut at a specific length, placed in a packaging enclosure and filled with an anolyte.
- 10 (6) In a sixth embodiment an Aluminum foil is unrolled and coated with a graphite slurry. This assembly is subsequently coated on the graphite side with an extrusion coated polymer foil using a physical or chemical foaming method. Next to this, the polymer foam can also be produced using a chemical reaction as described in the 4th embodiment. In a second roll-to-roll process the cathode is prepared by coating a substrate with a protective layer (such as TiN) via a physical vapor deposition process. This assembly is subsequently coated with a graphite slurry. The two coatings are merged and again the proper cell length is cut. The assembly is placed in a packaging enclosure and a KFSI salt based (potassium fluorosulfonylimide) electrolyte which is both an anolyte and catholyte is added to form a dual-ion battery cell.
- 15 20 (7) In a seventh embodiment the same strategy as described in the 6th embodiment can be applied, but here the polymer foamed separator is coated on the graphite slurry at the cathode side and an Aluminum foil is added to this stack to form the KFSI dual-ion battery.
- 25 (8) In a final embodiment the invention provides single Aluminum foils with the processing of the two half cells at each side and then stacked to form a battery pack.

The invention relates to producing open-cell foams, in particular by use of extrusion coating.

- 30 The invention relates to producing the above mentioned foams, for use in batteries or battery cells, and therefore, the used polymers are selected for being compatible with related electrolyte liquids, in particular since said foams are targeted for as battery separator.

Therefore appropriate cell opening properties and/or tunable pore sizes are preferably obtained by blending **several polymer matrices in order to obtain a structural inhomogeneity consisting of hard and soft regions, by combining semi-crystalline polymers with different crystallization temperatures.**

5

In an alternative embodiment to achieve the same, a (partial) polymer cross-linking strategy **can be used to obtain hard and soft regions in the initial polymer matrix.**

The above embodiment can be combined.

In a further embodiment a combination or blend of 2 or more polymer types in accordance with
10 the previous embodiments are used with a proper selection of the weight fractions of the polymers.

The invention uses a nucleating agent to initiate the cavity opening process. Nucleating agents can be (but are not limited to): calcium carbonate, calcium sulfate, magnesium hydroxide, calcium tungstate, magnesium oxide, lead oxide, barium oxide, titanium dioxide, zinc oxide,
15 antimony oxide, boron nitride, magnesium carbonate, lead carbonate, zinc carbonate, barium carbonate, calcium silicate, aluminosilicate, carbon black, graphite, non organic pigments, alumina, molybdenum disulfide, zinc stearate, PTFE particles, clay, calcium metasilicate, diatomaceous earth,

The invention further uses (and preferably in combination with the nucleating agent) a blowing
20 (foaming) agent. Both physical as chemical blowing foam formation strategies can be used. For the chemical foaming route it is possible to use inorganic and organic foaming agents. Examples of inorganic chemical foaming agents include sodium bicarbonate, ammonium carbonate, ammonium bicarbonate, and calcium azide. Examples of organic foaming agents include azodicarbonamide, hydrazocarbonamide, benzenesulfonyl hydrazide,
25 dinitrosopentamethylene tetramine, toluenesulfonyl hydrazide, p,p'-oxybis(benzenesulfonylhydrazide), azobisisobutyronitrile, and barium azodicarboxylate.

As mentioned the invention targets extrusion coating of the foam.

In a first embodiment thereof direct coating of a foamed polymer on an Al and graphite substrate is used. The polymer will be formulated with the additives and chemical blowing
30 agent. Moving from a high pressure environment to a low pressure environment at the dye exit

a foam will be formed and coated on the substrate where an optimized calendar roll gap will result in the desired foam separator on the substrate. A separate masterbatch with the foaming agent can be fed into the main hopper, or added later in the process via a side feeder. The output of the polymer melt can be controlled using a gear-pump.

- 5 In a second embodiment thereof the polymer will be compounded with a chemical blowing agent that reacts at a temperature that is higher than the extrusion temperature of the polymer. An extrusion coating of the polymer compound is applied. After extrusion the polymer coating will be heated again above the foaming temperature to form the desired foamed separator.

10 In case of use of a physical blowing agent, preferably CO₂ is used but other gasses such as nitrogen, argon, water, air, helium, hydrocarbons (such as methane, ethane, propane for example), alcohols (methanol, ethanol, isopropanol for example), chlorinated organic gasses and fluorocarbons can be suitable too.

- 15 In a third embodiment the additives are mixed in a twin screw extruder using a melt pump and die exit. The pressure drop is realized at the die exit. Preferably CO₂ is injected in a mixing zone at the end of the extruder in order to generate the desired polymer foam which is subsequently coated on the substrate.

20 In a fourth embodiment a tandem extrusion setup is used, where in a first extruder CO₂ is added and blend in a polymer melt. This blend is injected in a secondary extruder, fitted with a gear pump and cooling unit, situated at the die exit. Although a tandem extrusion setup is more complicated and can result in a higher investment cost, it allows for better control of mixing and temperature variations. The desired foam is then casted on the substrate after exiting the dye.

- 25 Variations of one or more of the above options are also possible, where components are blend in by a twin screw extruder in a first step. After cooling, the compound is later added in a single screw extruder where CO₂ is added to form the foamed polymer foils which is casted on a substrate.

30 Formed polymer foams will be directly casted at the die exit on the substrate via a calendar roll to control the thickness and cooling of the foam. The temperature at the dye exit and the aluminum substrate will be controlled in order to control the integrity of the foam.

Next to a nucleating agent and a suitable blowing agent, other additives are used. These additives will be chain extenders, acid scavengers, anti-oxidants, adhesion additives to improve aluminum substrate adhesion and plasticizers. In order to strengthen the inner walls of the foams, a cross-link approach can be used, where the polymer system might be cross-linked during extrusion or at the die exit. Alternatively post-foaming cross-linking strategies can be used. Cross-linking additives will depend on the nature of the base-polymers and the extrusion temperature but will mainly be focused on thermally activated systems, where for post-extrusion crosslinking also UV-initiated cross-linking additives can be suitable. Next to the nature of the base polymer blend and the additive's nature and concentration, also the extrusion temperature and pressure decrease at the die exit (ΔP) will be optimized, because these parameters greatly influence the density of the foam, the pore size and the open-cell content. The combination of polymer systems, additives, foaming agents and processing parameters will be optimized in such a way that the open cell content of the foam, dielectrically properties and size of pores are suitable for use as a battery separator with minimal foam density, maximal dielectrically properties and maximum pore size to allow for ionic transport. Next to this extrusion coating process on calendaring rolls will be optimized to obtain the appropriate thickness of the foam, adhesion and production homogeneity on the substrate.

In summary the invention provides:

- A battery, comprising (i) an anode, (ii) a cathode; (iii) a separator, in between said anode and said cathode; (iv) an electrolyte, in between said anode and said cathode, characterized in that said separator being a polymer or polymer compound, adapted for ion transport for the electro-chemistry system defined by said anode, cathode and electrolyte.
- A capacitor, comprising (i) an anode, (ii) a cathode; (iii) a dielectric, in between said anode and said cathode, characterized in that said dielectric being a polymer or polymer compound.
- A method of roll- or sheet-based manufacturing, based on extrusion coating and any other in-line continuous coating process, coating an arrangement of materials for use in such a battery or capacitor and finally combining before cutting those and related composition of materials comprising (i) granulates, (ii) one or more (foaming or dielectric) agents and/or coating materials.

Finally some further considerations in relation to the invention are provided below.

Throughout the description the word battery or capacitor is used but the invention also covers any part of a battery or capacitor such as any arrangement of materials for use in a battery or capacitor, including such arrangements denoted as a battery or capacitor cell, module and pack in the field.

- 5 Likewise, throughout the description the word battery or capacitor assembly is used. While assembly may read on all the necessary steps to result in a functional battery or capacitor or even a series connection of batteries or capacitors, again the invention also covers any part of a battery or capacitor, such as multilayer foil or sheet, being providable as a roll, on which subsequently (and possibly at a distant place) and depending on the required configuration
- 10 further other processes such as the providing of conductors for connecting purposes or insulators for heatsinking purposes are performed on and followed by cutting the resulting foil or sheet to thereby finishing the so-called battery or capacitor module or pack, which can then further on being connected in series or parallel for the modular build-up of an energy storage solution.
- 15 Note that the energy or capacity delivery parameters are essentially determined by the length of the cut sheet while the voltage delivery parameter is essentially determined by the amount of battery cells connected in series..

PACK EMBODIMENT

Given the above provided (multi-layers) foils in accordance with the invention, the invention further enables the composing of battery packs. The large area cells, in particular, are monolithically formed battery or capacitor modules in comparison to conventionally formed
5 battery or capacitor modules by tabbing, wiring, connecting and assembling multiple smaller battery or capacitor cells in parallel.

Figure 9 shows an exemplary embodiment with a multilayer structure, formable with the methods outlined above. Several of the above multilayer structures (which could be denoted modules) can now be stacked to form packs. In essence as schematically indicated the same
10 (continuous) large area foil (cut at the proper length though) is used and then further stacked. With providing the proper contacts at the appropriate places of the respective outer layers, the obtained cells are de-facto connected (as required in series and/or parallel). The obtained modules can then be further connected with same or similar modules when required.

Given the above provided (multi-layers) foils (that can be considered as modules) in accordance
15 with the invention, the invention further enables the composing of battery or capacitor packs, in particular bipolar stacked battery or capacitor packs.

Figure 10 shows repetitive (N-times) use of the methods outlined above.

Figure 11 shows an exemplary embodiment with a multilayer structure obtainable with the methods of Figure 9 or 10.

20 Figure 12 (left) shows an exemplary embodiment with a multilayer structure, formable with repetitive (N-times) use of the methods outlined above, to thereby obtain a battery or capacitor arrangement, which after providing connection means (tabs and related wires) result in (serial and/or parallel) connected cells in larger modules or packs.

Figure 12 (right) shows an exemplary embodiment with a multilayer structure, formable with
25 repetitive (N-times) use of the methods outlined above, to thereby obtain a battery or capacitor arrangement with (intrinsically) serial connected cells into packs.

The above indicated that in an embodiment of the invention one can aim for a battery or capacitor cell, comprising two foils or sheet, serving each as part of the anode or cathode respectively; and a separator and electrolyte or dielectric therein between, wherein said foils
30 or sheets are (nearly) identical and preferably identical.

The novelty of a cell architecture as part of the invention, is its symmetry with exactly the same substrate for the current collectors or capacitor plates at both sides of the battery or capacitor cell and where the current collector or capacitor plate substrates are at the same time the substrates used in and compatible with cheap and abundantly available production capacity. In
5 Li-ion cells, the current collector for the cathode is Al and for the anode Cu. Al cannot be used as current collector for the anode as it would dissolve in the electrolyte with the applicable strong redox potentials. Cu could be used as current collector for the cathode, but Cu is much less compatible and even not compatible with the intended mainstream production methods and is more expensive than Al. Current dual ion non rocking chair battery cells cannot use Al as
10 current collector at the cathode side as it would in a similar way dissolve in the electrolyte with the strong applicable redox potentials.

Therefore, the invented cell architecture comprises protection layers at one or both sides of the battery cell to enable symmetrical battery cells with current collector substrates that are preferentially cheap, abundant and used in mainstream high volume production environments
15 from unrelated sectors. Hence the cell architecture comprises two outer identical foils or sheets that are used in the cell production as substrates to coat all remaining cell components such as the protection layers, graphite layers and the separator or the dielectric in case of capacitors.

The symmetry, with Al foil as current collectors for battery cells at both sides enabled by the incorporation of cheap protection layers, has three major advantages that enables to reduce
20 the cell unit cost drastically.

Firstly, a single Al foil can be coated, calendered, dried and cut in segments in a continuous roll to roll process using mainstream extrusion coating, liquid coating, aerosol, sputtering, evaporation and other deposition techniques used in the plastic and paper packaging as well as in the semiconductor industries. Al has good mechanical properties such as tensile strength and
25 flexibility for cheap roll to roll processing. Al foil use is already based on 75% recycled Al and the recycling ecosystem is one of the most established among all materials. Hence the end of life cost remains cost competitive as well. So the distinctive feature of cell production enabled by the cell architecture versus current practices, is that no stacking or assembly occurs in order to finalize the complete battery cell. The avoidance of stacking or assembly at cell level greatly
30 enhances production throughput, hence lower unit cost of the final battery cell and pack. Another distinctive feature is that the cutting of segments of the complete foil determines the capacity and energy rating of the final battery system comprising the battery cells. In other

words, the foil battery cell is the monolithic equivalent of parallel connected small battery cells and assembled in what is known today as battery modules. The cost of tabbing, wiring, connecting, assembly and casing into a discrete module is completely eliminated and contributes greatly to the reduction of the unit cost of the final battery system.

- 5 The ease of cutting segments of the battery foil gives cell producers an additional competitive advantage where supply and demand in terms of capacity and energy ratings can be met instantly at the cell factory. There is no need for line reconfigurations and no need to transport battery cells to assembly factories. The same advantages hold for the capacitor arrangements.

The symmetry of the cell and the possibility to process all the cell components on a single Al foil
10 with each half cell at both sides of the single Al foil, also allows to stack a multitude of these cells on top of each other whereby the stack volumetric and gravimetric energy and power density is exactly the same as the volumetric and gravimetric cell densities of each individual cell in the stack. In other words, the cell architecture allows the production of battery packs without the need for individual tabbing, wiring, connection, assembly and casing of the
15 constituent battery cells greatly contributing again to the reduction of the unit cost of the final battery system. The inferior battery cell density as a result of selecting battery cell technologies that use as much as possible simple and easily fabricated coatings using cheap, abundant and easily recyclable materials is greatly compensated with the optimal battery pack density that otherwise can never be obtained when not applying the battery cell architecture. The novel
20 battery cell architecture leads to a novel stack architecture for the battery pack of which the width and length determine the capacity and the energy rating of the final battery pack whereas the height of the stack determines the voltage and power rating.

The compact stack, where width, length and height can be easily selected in the battery cell factory across a continuum in terms of dimensions, can accommodate any available casing such
25 as standard shipping containers, thereby realizing optimal fill factors only constrained by payload considerations for transportation. The same advantages hold for capacitor arrangements.

The battery stack can be further enhanced with an embedded cooling system whereby the outer Al foils used for the battery cells are larger than the processing area needed. The extensions in
30 both planar directions around the final battery cell are effective heat sinks that can be complemented with a passive or active cooling system. The Al foils of the stack could reside in

a chamber comprising an insulating coolant between the casing around the battery stack and an outer casing and whereby the coolant can be stationary or actively circulated and cooled via an external heat exchanger. The waste heat could be further used for energy generation or storage. The Al foils could also be further extended outside the coolant chamber exposed to the ambient temperature of air. The inner and outer casings of the coolant chamber also have excellent thermal properties to effectively evacuate together with the other constituents of the cooling system the heat generated by the stack. Furthermore, insulating layers can be coated on the edges of the current collector or capacitor plate foils before cutting the foil or sheet, the same way the other cell components are processed, but on other areas of the foil at possibly other locations in the manufacturing line.

Figure 15 illustrates a stack provided with heat exchange elements. (2000) denotes a heat exchanging electrically non-conductive medium or circulating coolant (fluid, gas or air). (2010) represents a chamber (dashed line) in casing with thermally conductive walls holding the coolant. In case no such chamber is provided, the insulated AL foils or current collector or capacitor plate are exposed in ambient air. A combination of these techniques can be used. (2020) shows an electrical insulator layer but adapted for heat sinking.

Given the distinctive nature of the large area battery cells without need for assembly of a large number of small battery cells into modules and modules into packs, the battery management system and its related models, algorithms, software and hardware implementations will be fundamentally different from existing systems. The cell count is drastically reduced. Cell balancing might not be required when process variability for the cell making is reduced to a minimum threshold level. The use of a single Al foil and only a few and well known coating processes will greatly enhance minimum process variability in comparison with current practices for cell making. When cell balancing is not required, a black box approach for the modeling of the stack with the number of cells and their dimensions as a variable could lead to a fairly simple and cheap battery management system of which programmable electronics can be highly integrated, hence small form factor.

Given the cell architecture relies on the electrolyte as source for both ions to be stored at both sides of the battery cell, changes in the mass or gravity of the electrolyte while charging or discharging can be monitored to deduce the state of charge of a battery cell. Again when the process variability of the cell making across all cells is reduced below a certain threshold, the monitoring of one battery cell in the stack can be sufficient to deduce the state of charge of the

full stack thereby reducing the cost of sensors, wiring and control electronics significantly. Likewise, the monitoring of the capacitance of the stack is a cheap black box approach to determine the state of health of the battery stack and its constituent battery cells when process variability in the cell making is below a certain threshold level.

- 5 For certain electrolytes, the voltage curve of the stack is expected to be very flat. This is a desirable characteristic as it contributes to a higher round-trip efficiency. With a flat voltage curve, the resolution of the voltage sampling needs to be extremely high to accurately monitor the state of charge and health of the battery stack. Therefor programmable logic based on physical models of the battery stack that enables real-time, deterministic and fast control loops
- 10 will be used. In case the process variability in cell making cannot be reduced below a certain threshold level and therefore cell balancing (both electrically and thermally) in the stack is required during charging and discharging, programmable logic handling all cells will greatly enhance the cycle life of each individual cell, hence the cycle life of the stack.

- Finally, as mentioned earlier, the dimensions of the battery stack can be instantly selected in
- 15 the battery cell factory, hence the height can be selected to match optimally the required voltage level of the grid or micro-grid coupling. In doing so, grid integration becomes easier and less expensive by avoiding transformers and converters and by using standard inverters. Hence cell making flexibility enabled by the cell architecture not only allows a broad product variety for many applications on the same cell making line, but it also allows to minimize cost at system
- 20 level.

- Next to the use of protective layers that allows symmetrical battery cells produced using Al foils and mainstream coating production, a truly 100% continuous inline cell making process without a single stacking or assembly step during the cell making is enabled via an inline coating process of the separator on the anode side of the same Al foil. Today battery cells are stacked by
- 25 assembling the two electrodes with a separator in between. The separator today is always fabricated separately and supplied by a contractor to the cell maker. Instead of supplying a separator, a master batch that can be easily transported in bulk will be a consumable used in the cell making. When according to the state of the art, the three throughput times of the three coating processes for the protective, graphite and separator layers are quite close, a continuous
- 30 roll to roll process will result in maximal throughput of the cell making process compared to current cell production. Given the simple binning of large area cells at the end of the line into stacks, the stack throughput will definitely beat the current production throughput of packs.

With larger battery cells and a smaller cell count in a stack, electrolyte filling is also expected to take less time than current filling of a much larger count of small cells requiring much more complex robotics. Also the sealing of all the battery cells simply binned and stacked on top of each other is expected to be done in batches of a multitude of cells rather than the sealing of each individual cell. Likewise, the providing of necessary insulating materials around the current collectors or capacitor plates for cooling purposes avoid tedious and costly assembly afterwards.

In other words, the described large area cell architecture leads to many advantages related to the product, production and integration of the product in its environment typically grids, and foremost to cost effective levels in terms of power and energy ratings. Similar advantages holds for capacitor arrangements.

Finally, the large areas of the battery or capacitor cells that can be made by using the novel cell architecture and employing all inline roll to roll coating processes can not be made with current state of the art cell making processes which involves anyhow stacking or assembly steps. The surface dimension of the cell is constrained by the largest substrate that can be made with state of the art machinery. Especially the complexity of current and emerging coatings for the cathode as well as the anode (e.g. Si rather than graphite anodes, or Li titanate) is the limiting factor and will continue to be a limiting factor because of the very nature of the electrochemical working principles. It is extremely difficult to maintain the right stoichiometry of a complex compounded layer (mostly oxides) on larger surfaces due to process limitations. Furthermore, maintaining the same process conditions across millions of cathodes will be more challenging with larger surfaces. Therefore, the cell architecture enabling the use of mainstream proven large scale coating methods leads to cell areas that are not attainable with current state of the art cell making methods. Therefore, battery or capacitor cells much larger than 100 cm² is a novelty in itself. A cell stack or pack much larger than 100 cm² is also non existing today. Furthermore, in principle the upper limit on the cell surface is only constrained to the longest Al foil rolls available in the industry as well as the widest rolls that can be used in coating the layers required in the battery or capacitor cell architecture. Furthermore, a cell stack or pack using double sided electrodes is also a novelty. Cells or stacks using the current collectors or capacitor plates as heat sinks is a novelty. Cells or stacks using inline coated separators is a novelty. Finally cooling systems embedded with the cell stack and the use of programmable controllers that provide real-time, deterministic and safe control loops and that easily scale with

a larger number of large area cells in a stack are novelties at system level. The cell architecture enables bipolar stacking leading to a transversal electronic charge flow across the whole Al foil surface as opposed to a lateral flow in current battery cells. This allows the Aluminum foils to be thinner and a more homogenous interface kinetics and heat spreading is obtained.

- 5 Next to battery cells and stacks, the method of continuous inline processing of dielectric layers is also suitable for large area super capacitors and stacks whereby on a single Aluminum foil a high dielectric coating is extrusion or liquid coated or tape casted on both sides and calendered with two other Al foils to form a dual stacked capacitor with one common capacitor plate. This process can be repeated whereby again under and above the dual stack the same dielectric is
- 10 extrusion or liquid coated or tape casted and calendered with two other Aluminum foils to form a quaternary stacked super capacitor with three common plates. An n stacked capacitor would have (n-1) common plates essential to avoid air or water in between two subsequently stacked capacitors. Otherwise the permittivity of the air or water in between would drastically lower the capacitance of the whole stack. Furthermore, the method is enabling ultra high voltage
- 15 super capacitors easing grid integration and eliminating power electronics such as transformers, converters and switches. The dielectric is a composite of high dielectric ceramic powders such as BaTiO_3 , SrTiO_3 , $\text{Ba}_x\text{Sr}_{1-x}\text{TiO}_2$ and $\text{CaCu}_3\text{Ti}_4\text{O}_{12}$ in a polymer matrix that can be extrusion or liquid coated or tape casted on large surface Al foils. Extremely thin layers of the dielectric coating and extreme large areas can be rolled up given the flexibility of the resulting foil. As the
- 20 capacitance is proportional to the permittivity of the layer and the surface of the Aluminum foils and inversely proportional to the thickness of the dielectric layer in between the Aluminum foils, this method leads to extremely high capacitance densities useful in grid applications e.g. to stabilize voltage, power quality, frequency, temporal storage, etc.... Furthermore, extremely high voltage stacked capacitors can be realized and the response and switching speeds are
- 25 extremely high compared to conventional super caps or batteries used for ancillary grid services. It is also expected that the composite when well selected can demonstrate extremely high thermal stability and potentially also stress stability again contributing to high Q factors, hence power quality in the grids. Needless to mention that the cell is much simpler in comparison to the symmetrical cell architecture proposed for batteries especially given the solid
- 30 nature of the layer in between the Aluminum foils and the fact that no leakage and corrosivity issues are present making those devices extremely safe in comparison with conventional super caps using electrolytes. Furthermore, given the use of mainstream roll to roll, cutting and binning manufacturing methods, the fast scaling and doubling of manufacturing capacity in the

plastic packaging industry, these super caps will have definitely an order of magnitude lower capacitance and power unit costs than any super cap technology presently available in the market. Given the modular nature of the storage unit, cost effective mass storage becomes possible and storage units can be easily transported to another location in the grid when
5 desired.

The above considerations can be reformulated as follows:

In a further embodiment thereof in this battery cell at least one of said foils or sheet, preferably both, are provided with a protection layer to protect against dissolvment of (part of) said foil
10 or sheet in the electrolyte.

Within those concepts of the battery cells one may elect to implement a dual ion cell.

It is also worth noting that in the above battery cells the anode and/or cathode are designed for simultaneous acting as charge storage and current collection, more in particular said charge storage function being provided by use of graphite deposition processing to thereby create an
15 active layer.

In an exemplary embodiment the cathode and/or the anode, preferably both, is based on a Al foil, preferably provided with protection layer provided on top thereof.

In a further advantageous embodiment the cathode and/or the anode, preferably both, are used as heat sink (by designing the surface of the current collectors or capacitor plates such that
20 those are larger than the active area of the cell and designed for exposure to ambient air and/or for soaking in an (electrically insulating) coolant, possible in combination with active circulation of the coolant). These current collectors or capacitor foils can be first provided with insulating layers at the edges before cutting.

It is also worth emphasizing that the above outlines approaches enabling manufacturing of
25 battery or capacitor cells wherein the anode and cathode surface exceeds 100 cm^2 .

Note that the above approaches enable manufacturing of foils or sheets which may be considered as half-cells, in that when properly combined defines cells. Within such approach those battery cells will share a common foil or sheet as current collector or capacitor plate.

Therefor one may consider a battery or capacitor arrangement, up to even a pack, comprising a plurality of battery or capacitor cells, wherein subsequent battery or capacitor cells share a foil or sheet.

5 With reference to the exemplary embodiment above the invention also discloses an Al foil or sheet, suitable for use in a battery or capacitor cell (or the monolithic equivalent of a module), as anode or cathode, characterized that said foil or sheet is provided with a protection layer, especially on the cathode side.

In a further embodiment thereof said foil or sheet is supplemented with a graphite deposition, to thereby create an active layer to provide a charge storage function.

10 The above mentioned foil or sheet is hence typically provided with said one or more of said layers on both sides, and preferably also provided with said separator.

The related manufacturing methods for said (nearly) identical foil cells can be described as follows:

15 The invention indeed provides a method of roll or sheet based manufacturing an arrangement of materials for use in a battery or capacitor cell, comprising the steps of: (i) providing a (carrier) material, suitable to act as anode or cathode, as a sheet or foil; (ii) providing one or more further materials on said material.

In a first embodiment said further material is suitable to act as separator, preferably said further material is adapted to endure the presence of electrolyte.

20 In a second embodiment said further material is suitable to act as active material within a battery to provide a charge storage function.

In a third embodiment said further material is suitable to act as protective layer on said (carrier) material (to protect against dissolvment of (part of) said foil or sheet in the electrolyte).

25 Based on the above the invention also discloses a method to manufacture a battery or capacitor (cell), comprising (a) executing of any and one or more of the methods described above a first time (in consecutive steps); (b) executing of any and one or more of those methods a second time on the other side of the (carrier) material used in step (a).

For sake of completeness, for the invented storage devices (battery (cell), capacitor) with its structural and/or electrical characteristics, alternative and more suitable monitoring and/or control methods can be used, leveraging on those characteristics.

Therefore the invention further relates to:

- 5 • State-of-charge / discharge capacity monitoring via indirect specific gravity monitoring through hydrostatic pressure and/or other float level measurements of the electrolyte. By measuring (semi-) continuously the height of the liquid and the hydrostatic pressure in one or multiple points, the changing electrolyte density is obtained. In essence two small sensors probing the liquid in one or several or all cells in a stack are used. Given
10 that the source of the dual ions is the electrolyte, a sensible change in the electrolyte density will occur from discharged to charged states and vice versa. Measuring the curve that relates electrolyte density with the capacity of the cell provides the model to be used in a BMS (battery measurement system). Especially seen that the voltage curve of the KFSI cell is extremely flat, the voltage method is useless unless you can monitor
15 voltage changes with extreme high resolutions which requires high performance based micro controllers not available today. On top it might be necessary to monitor cell voltages instead of stack voltages and with a larger number of cells the computing requirements of controllers become even more challenging, hence expensive.
- 20 • The invention also presents state-of-charge / discharge capacity monitoring via use of a voltage controlling real-time programmable logic using ultra high voltage resolution to be able to monitor capacity on the flat voltage curve of KFSI cells or stacks (stacks need higher resolutions than cells as the absolute value is higher at stack level so same deviations are much smaller percentages than at cell level). The programming of the logic can be based on detailed characterization based on prior method (using
25 hydrostatic pressure and at least one other accurate float level measurement technique) even considering ageing with characterization across an accelerated ageing cycle life. The incorporation of ageing data in the programming of the logic has the advantage of not having to calibrate during the lifespan, hence avoid maintenance on site. Also characterization of a multitude of cells and simultaneous high resolution
30 monitoring of the stack voltage could reveal an accurate black box monitoring method at stack level which would reduce considerably H/W and S/W expenses. Note that the

larger the cells in area, the more variabilities are cancelled out leading to effective black box control at stack level.

- The invention further presents charging / discharging controller based on the same programmable platform. Next to voltage monitoring above during characterization, also capacitance and currents are monitored to generate additional datasets for the programming of the logic in order to optimize cycle life of cells, hence stacks.
- The invention further presents state of health monitoring based on the same programmable platform based on capacity monitoring towards highest saturating voltage level.

The invention provides an advantageous use of the programmable logic approach in that proprietary datasets, generated specifically related to each electrolyte used in the proposed cells, are used, in particular for the dual ion single (dual) graphite battery arrangements described though out the entire description.

The invention can be formalized as follows :

1. A battery, comprising (i) a anode, (ii) a cathode; (iii) a separator, in between said anode and said cathode; (iv) an electrolyte, in between said anode and said cathode, characterized in that said separator being a foamed polymer or foamed polymer compound, adapted for ion transport for the electro-chemistry system defined by said anode, cathode and electrolyte.
2. The battery of 1, wherein said separator is contacting either said anode, said cathode or both.
3. The battery of 2, wherein said separator contacting both said anode and said cathode and said electrolyte being substantially being provided inside part of said separator, which is adapted therefore.
4. The battery of 2, wherein said separator is secured or fixed to either said anode, said cathode or both.
5. The battery of any of the previous possibilities, whereby said foamed polymer being adapted to endure the presence of said electrolyte, in particular said foamed polymer being cross-linked.
6. The battery of any of the previous possibilities, whereby the foamed polymer comprising an open cell structure.

7. The battery of any of the previous possibilities, whereby either said anode or said cathode or both being of a single material or a complex (layered, compounded, alloyed, meshed, perforated, roughened (to increase the contact surface for active layer loading) or laminated with a rough or roughened carrier) structure.
- 5 8. The battery of any of the previous possibilities, wherein either said anode or said cathode or both being coated with one or more coatings.
9. The battery of any of the previous possibilities, wherein the material, structure and/or coatings being suitable for use in roll to roll manufacturing of either said anode or cathode or both.
- 10 10. The battery of any of the previous possibilities, wherein the material, structure and/or coatings being suitable for use in roll to roll continuous manufacturing of the in-line secured (integrated or embedded) separator anode or cathode arrangement.
11. The battery of any of the previous items, wherein said anode is Al or any conducting materials with or without a carrier especially alkali metals such as potassium, calcium,
15 sodium, magnesium, lithium, carbon materials such as carbon powders, graphites in any form, nanotubes, nanorods, nanobuds, graphene, superconductors with a coating of active materials such as graphite, all kind of carbons, silicon, polypyrene etc...
12. The battery of any of the previous items, wherein said cathode is any conducting materials with or without a carrier such as ... TiN, CrN, Tungsten or any of the aforementioned
20 conducting materials from the anode side with a coating of active materials such as graphite, all kind of carbons, silicon, etc...
13. A method of roll or sheet-based manufacturing an arrangement of materials for use in a battery as in 1, comprising the steps of: (i) providing a (carrier) material, suitable to act as anode or cathode, as a sheet or foil; (ii) providing a foamed polymer on said material,
25 suitable to act as separator.
14. The method of 13, wherein step (ii) comprises an (extrusion) coating process, provided with (i) granulates, defining said polymer and (ii) one or more foaming agents.
15. The method of 14, wherein said (extrusion) coating process is further provided with one or more additives to secure said foamed polymer to said anode or cathode foil.
- 30 16. The method of 15, comprising a step for securing said foamed polymer to said (carrier) material, more in particular said step is a pressurizing step.
17. The method of any of the above , further comprising a step of ensuring that the foamed polymer is adapted to endure the presence of said electrolyte, in particular by ensuring

cross linking in said polymer, in particular but not limited thereto said step is a UV curing and/or heating step.

18. A composition of materials, selected for use in said method of any of the above claims, comprising (i) granulates, defining said polymer or polymer compound, (ii) one or more
5 foaming agents.
19. The composition of materials of 17, further comprising (iii)) one or more additives such as, but not limited to, adhesion improvement agents, anti-oxidants, colouring agents such as dyes and pigments, processing aids, fillers, anti-static agents, agents that influence the conductivity of the polymer matrix.
- 10 20. A method for providing a battery as in 1, customized in terms of one or more parameters, the method comprising: (i) loading said parameters; (ii) determining the length and/or width of said anode and/or cathode, based on said parameters; (iii) providing said anode and/or cathode with said determined length and/or width by cutting an arrangement of material comprising a (carrier) material, suitable to act as anode or cathode; and a foamed
15 polymer , suitable to act as separator, on said material, optionally manufactured with the method of any of the items 13 to 17; and (iv) assembling a battery cell therewith.
21. The method of 20, wherein said step of cutting being part of sheet or roll-based processing.
22. A foil or sheet for use in (manufacturing, preferably in accordance with the method of 20 or 21) the battery of 1, said foil or sheet optionally being manufactured by the methods of 13
20 to 17, said foil or sheet comprising a (carrier) material, suitable to act as anode or cathode; and a foamed polymer on said material, suitable to act as separator.
23. The foil or sheet of 22 being provided in a roll.
24. The foil or sheet of 22 or 23, wherein said foamed polymer is secured with additives on said (carrier) material.
- 25 25. The foil or sheet of any of the 22 to 24, wherein said foamed polymer is adapted to endure the presence of electrolyte, in particular by ensuring cross linking in said polymer.
26. A method of roll or sheet based manufacturing an arrangement of materials for use in a battery cell, comprising the steps of: (i) providing a (carrier) material, suitable to act as anode or cathode, as a sheet or foil; (ii) providing a further material on said material,
30 suitable to act as separator, preferably said further material is adapted to endure the presence of electrolyte.
27. A method for providing a battery cell, customized in terms of one or more parameters, the method comprising: (i) loading said parameters; (ii) determining the length and/or width of

- said anode and/or cathode, based on said parameters; (iii) providing said anode and/or cathode with said determined length and/or width by cutting an arrangement of material comprising a (carrier) material, suitable to act as anode or cathode; and a further material, suitable to act as separator, on said material optionally manufactured with the method of
- 5 26; and (iv) assembling a battery therewith.
28. The method of 27, wherein said step of cutting being part of sheet or foil based processing.
29. A foil or sheet for use in (manufacturing, preferably in accordance with the method of 27 or 28) a battery, said foil or sheet optionally being manufactured by the methods of 26, said foil or sheet comprising a (carrier) material, suitable to act as anode or cathode; and a
- 10 further material on said material, suitable to act as separator.
30. The foil or sheet of 29 being provided in a roll.
31. The foil or sheet of 29 or 30, wherein said further material is secured with additives on said (carrier) material.
32. The foil or sheet of any of the 29 to 31, wherein said further material is adapted to endure
- 15 the presence of electrolyte.
33. A method of foil or sheet based manufacturing an arrangement of materials for use in a battery, comprising the steps of: (i) providing a (carrier) material, as a sheet or foil; (ii) providing a further material on said material, suitable to act as active material within a battery.
- 20 34. The method of 33, wherein step (ii) comprises an (extrusion) coating process or an aerosol technique.
35. A method for providing a battery cell, customized in terms of one or more parameters, the method comprising: (i) loading said parameters; (ii) determining the length and/or width of said anode and/or cathode, based on said parameters; (iii) providing said anode and/or
- 25 cathode with said determined length and/or width by cutting an arrangement of material comprising a (carrier) material; and a further material, suitable to act as active material within a battery cell, on said material, optionally made by the method of 33 or 34; and (iv) assembling a battery therewith.
36. The method of 35, wherein said step of cutting being part of sheet or foil based processing.
- 30 37. A foil or sheet for use in (manufacturing, preferably in accordance with the method of 35 or 36) a battery, said foil or sheet optionally being manufactured by the methods of 33 or 34, said foil or sheet comprising a (carrier) material; and a further material on said material, suitable to act as active material in a battery cell.

38. The foil or sheet of 37 being provided in a roll.
39. A method to manufacture a battery, comprising executing of the method of 33 a first time to provide an anode by providing a Al sheet and providing graphite (via slurry coating) as further (active) material thereon (and thereafter a separator material thereon); executing
5 of the method of 33 a second time to provide a cathode by providing a plastic sheet and providing first a carbon layer (such as nanotubes, nanobuds, graphene, etc... via an aerosol technique) as further material thereon (and thereafter (via slurry coating) a graphite layer thereon); and finally combining both generated arrangements of material.
40. A battery arrangement, comprising a plurality of battery parts, each derived from the same
10 foil or sheet as in 38, said parts being provided with means to realize (serial and/or parallel) connection of said parts when put next to each other in one such arrangement.
41. A battery arrangement, comprising a plurality of battery parts (which are serial connected), each derived from sequential applying the method of 39 on a previously obtained foil.
42. The battery arrangement of 41, wherein the outer battery parts are provided with means
15 to realize external connection of said parts.

As said lot of the considerations above can be made also for a capacitor in which case a dielectric layer is provided instead of a separator.

Claims

1. A battery (cell), comprising (i) a anode, (ii) a cathode; (iii) a separator, in between said anode and said cathode; (iv) an electrolyte, in between said anode and said cathode, characterized
5 in that said separator being a foamed polymer or foamed polymer compound, adapted for ion transport for the electro-chemistry system defined by said anode, cathode and electrolyte.
2. The battery (cell) of claim 1, wherein said separator is contacting either said anode, said cathode or both.
- 10 3. The battery (cell) of claim 2, wherein said separator contacting both said anode and said cathode and said electrolyte being substantially being provided inside part of said separator, which is adapted therefore.
4. The battery (cell) of claim 2, wherein said separator is secured or fixed to either said anode, said cathode or both.
- 15 5. The battery (cell) of any of the previous claims, whereby said foamed polymer being adapted to endure the presence of said electrolyte, in particular said foamed polymer being cross-linked.
6. The battery (cell) of any of the previous claims, whereby the foamed polymer comprising an open cell structure.
- 20 7. The battery (cell) of any of the previous claims, whereby either said anode or said cathode or both being of a single material or a complex (layered, compounded, alloyed, meshed, perforated, roughened or laminated with a rough or roughened carrier) structure.
8. The battery (cell) of any of the previous claims, wherein either said anode or said cathode or both being coated with one or more coatings.
- 25 9. The battery (cell) of any of the previous claims, wherein the material, structure and/or coatings being suitable for use in roll to roll manufacturing of either said anode or cathode or both.
10. The battery (cell) of any of the previous claims, wherein the material, structure and/or coatings being suitable for use in roll to roll continuous manufacturing of the in-line secured
30 (integrated or embedded) separator anode or cathode arrangement.
11. The battery (cell) of any of the previous claims, wherein said anode is Al or any conducting materials with or without a carrier especially alkali metals such as potassium, calcium, sodium, magnesium, lithium, carbon materials such as carbon powders, graphites in any

form, nanotubes, nanorods, nanobuds, graphene, superconductors with a coating of active materials such as graphite, all kind of carbons, silicon, etc...

12. The battery (cell) of any of the previous claims, wherein said cathode is any conducting materials with or without a carrier such as ... TiN, CrN, Tungsten or any of the
5 aforementioned conducting materials from the anode side with a coating of active materials such as graphite, all kind of carbons, silicon, etc...
13. A battery (cell) as in any of the previous claims, comprising two foils or sheet, serving each as part of said anode or said cathode respectively, wherein said foils or sheets are identical.
14. The battery (cell) of claim 13, wherein at least one of said foils or sheet, preferably both are
10 provided with a protection layer (TiN, CrN, Tungsten) to protect (or being (corrosion resistant or oxidative stable) against dissolvment of (part of) said foil or sheet in the electrolyte.
15. The battery (cell) of any of the above claims, being a dual ion cell.
16. The battery (cell) of any of the above claims, wherein the anode and/or cathode being
15 designed for simultaneous acting as charge storage place and current collection.
17. The battery (cell) of claim 16, wherein said charge storage place function being provided by use of graphite deposition processing to thereby create an active layer.
18. The battery (cell) of any of the above claims 13 to 17, wherein the cathode and/or the anode, preferably both, is based on a Al foil, preferably provided with protection layer
20 provided on top thereof.
19. The battery (cell) of any of the above claims, wherein the cathode and/or the anode, preferably both, are used as heat sink (by designing the surface of the current collectors such that those are larger than the active area of the cell and designed for exposure to ambient air and/or for soaking in an (electrically insulating) coolant, possible in
25 combination with active circulation of the coolant), possibly provided by an insulating but thermally conducting layer at the edges outside the active area on the current collectors before cutting the foil
20. A method of roll or sheet based manufacturing an arrangement of materials for use in a battery (cell), comprising the steps of: (i) providing a (carrier) material, suitable to act as
30 anode or cathode, as a sheet or foil; (ii) providing one or more further materials on said material.
21. The method of claim 20, wherein said further material being suitable to act as separator, preferably said further material is adapted to endure the presence of electrolyte.

22. The method of claim 20, wherein said further material, suitable to act as active material within a battery to provide a charge storage function.
23. The method of claim 20, wherein said further material, suitable to act as protective layer on said (carrier) material (to protect against dissolvment of (part of) said foil or sheet in the electrolyte).
24. A method to manufacture a battery (cell), comprising (a) executing of any and one or more of the methods of claim 20 to 23 a first time (in consecutive steps); (b) executing of any and one or more of the methods 20 to 23 a second time on the other side of the (carrier) material used in step (a).
25. The method of 21, wherein said separator being a foamed polymer, comprising an (extrusion) coating process, provided with (i) granulates, defining said polymer and (ii) one or more blowing or foaming agents, preferably also nucleating agents are used.
26. The method of claim 25, wherein said (extrusion) coating process is further provided with one or more additives to secure said foamed polymer to said anode or cathode (foil).
27. The method of claim 21, comprising a step for securing said foamed polymer to said (carrier) material, more in particular said step is a pressurizing step.
28. The method of any of the above claims 25 to 27, further comprising a step of ensuring that the foamed polymer is adapted to endure the presence of said electrolyte, in particular by ensuring cross linking in said polymer, in particular but not limited thereto said step is a UV curing and/or heating step.
29. A method for state-of-charge/discharge level monitoring of any of the above battery cells, comprising: sensing the hydrostatic pressure combined with float level measurements of the electrolyte; and based thereon compute the density hence the state-of-charge/discharge status.
30. A method for charging / discharging control of any of the above battery cells, comprising: monitoring one or more of the following: voltage, capacitance and currents; and based thereon determine suitable control signals.
31. A data processing system comprising means for carrying out the method of any of claims 29 or 30, preferably a programmable logic, and optionally a computer program comprising software code adapted to perform the method of any of claims 29 or 30, and further optionally a computer readable storage medium comprising said computer program.

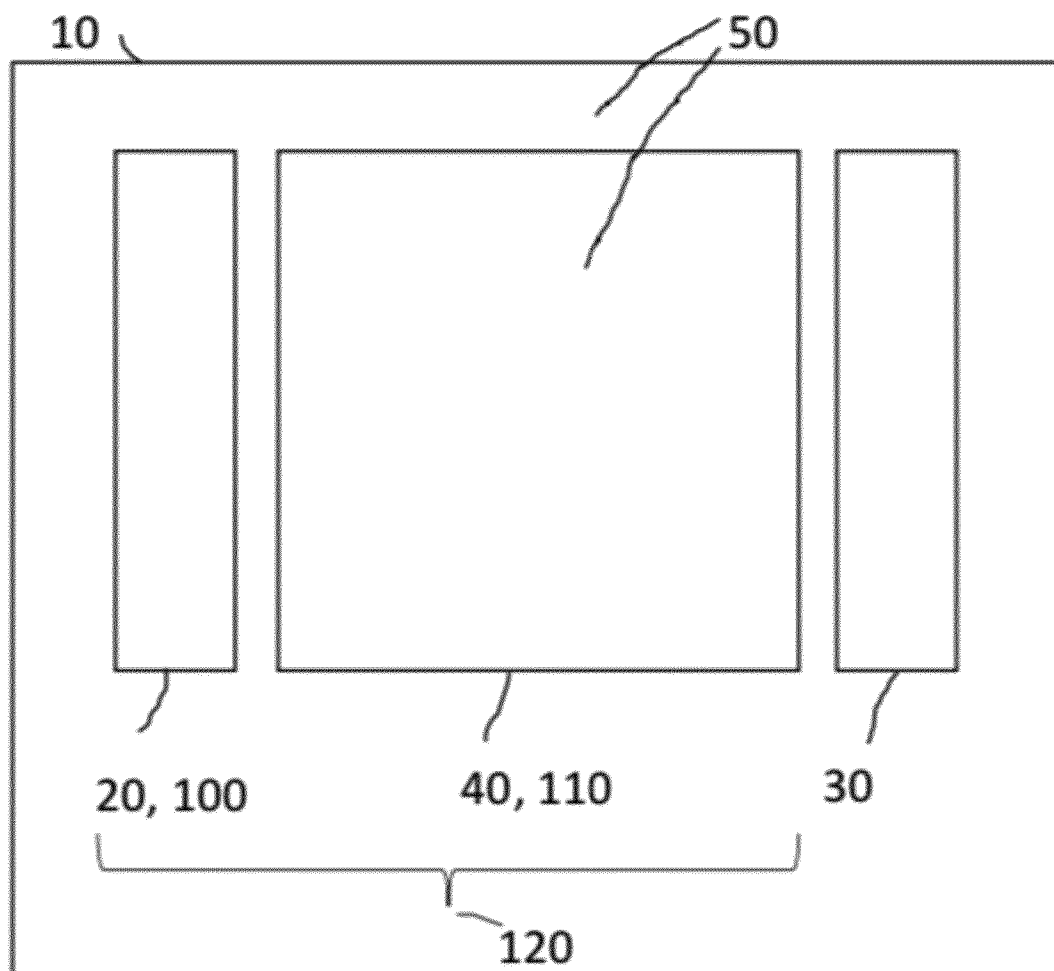


Fig. 1

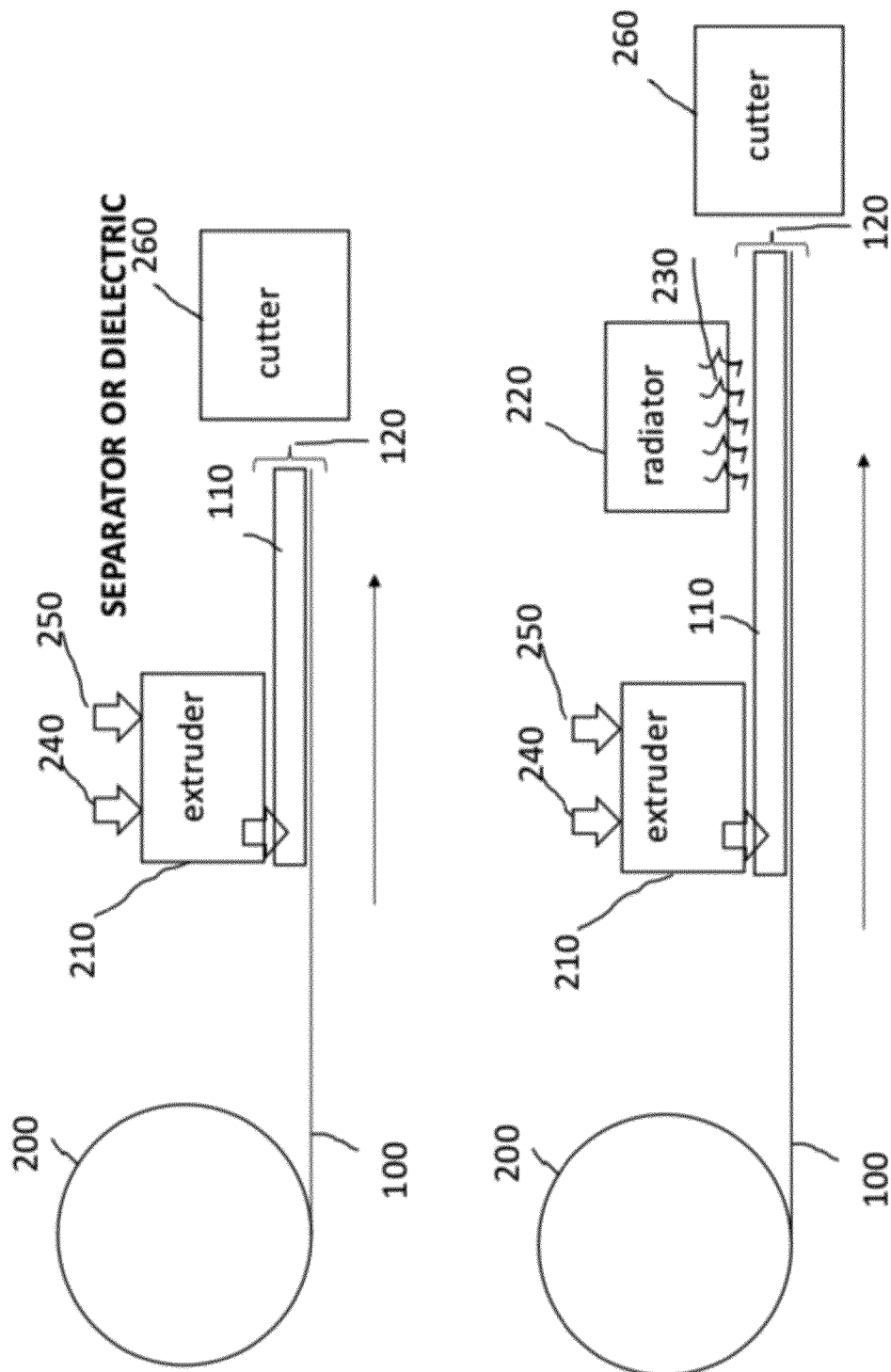


Fig. 2

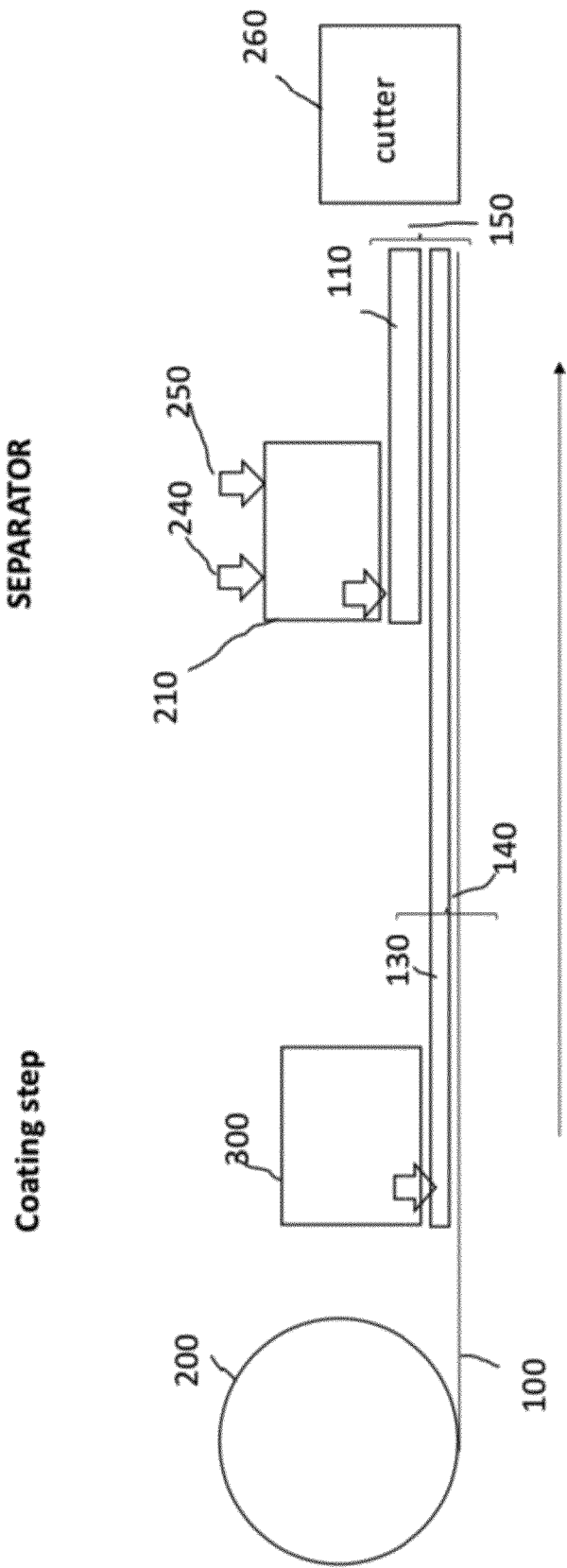


Fig. 3

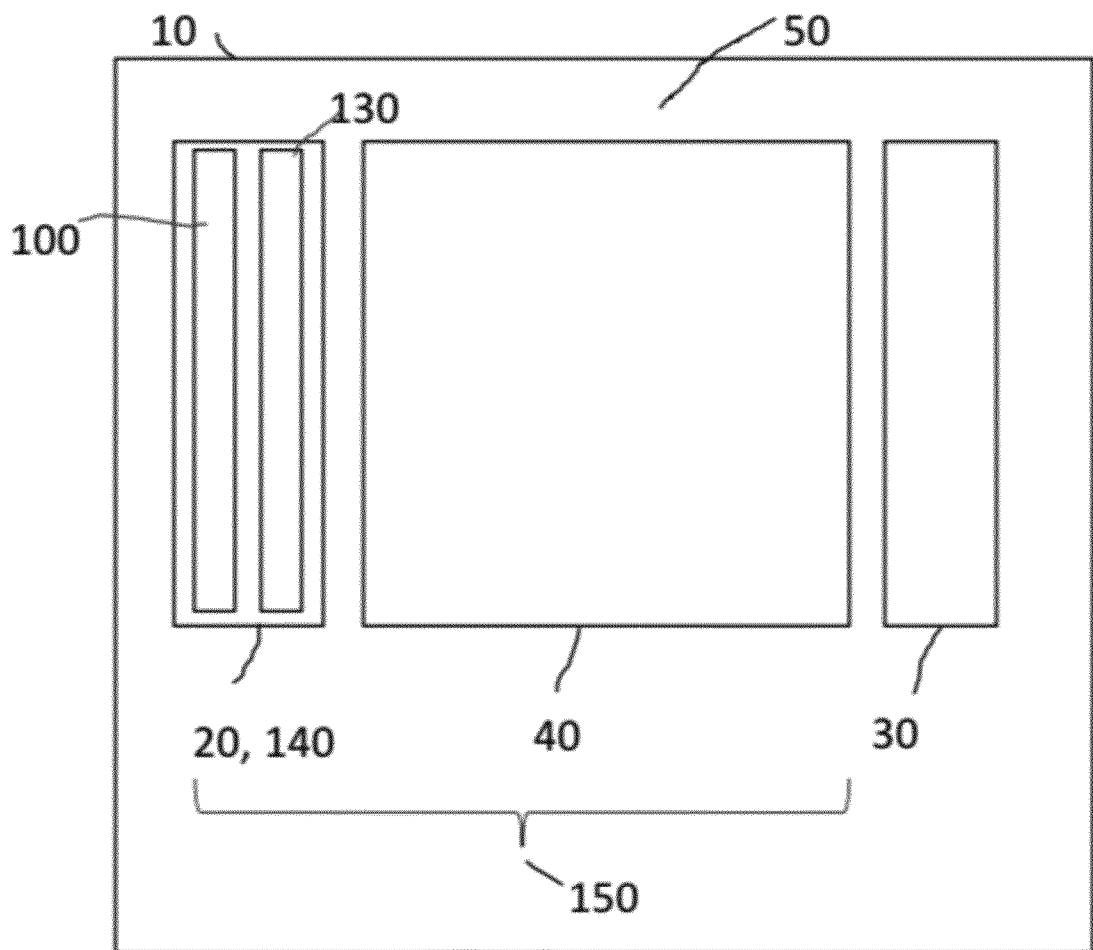


Fig. 4

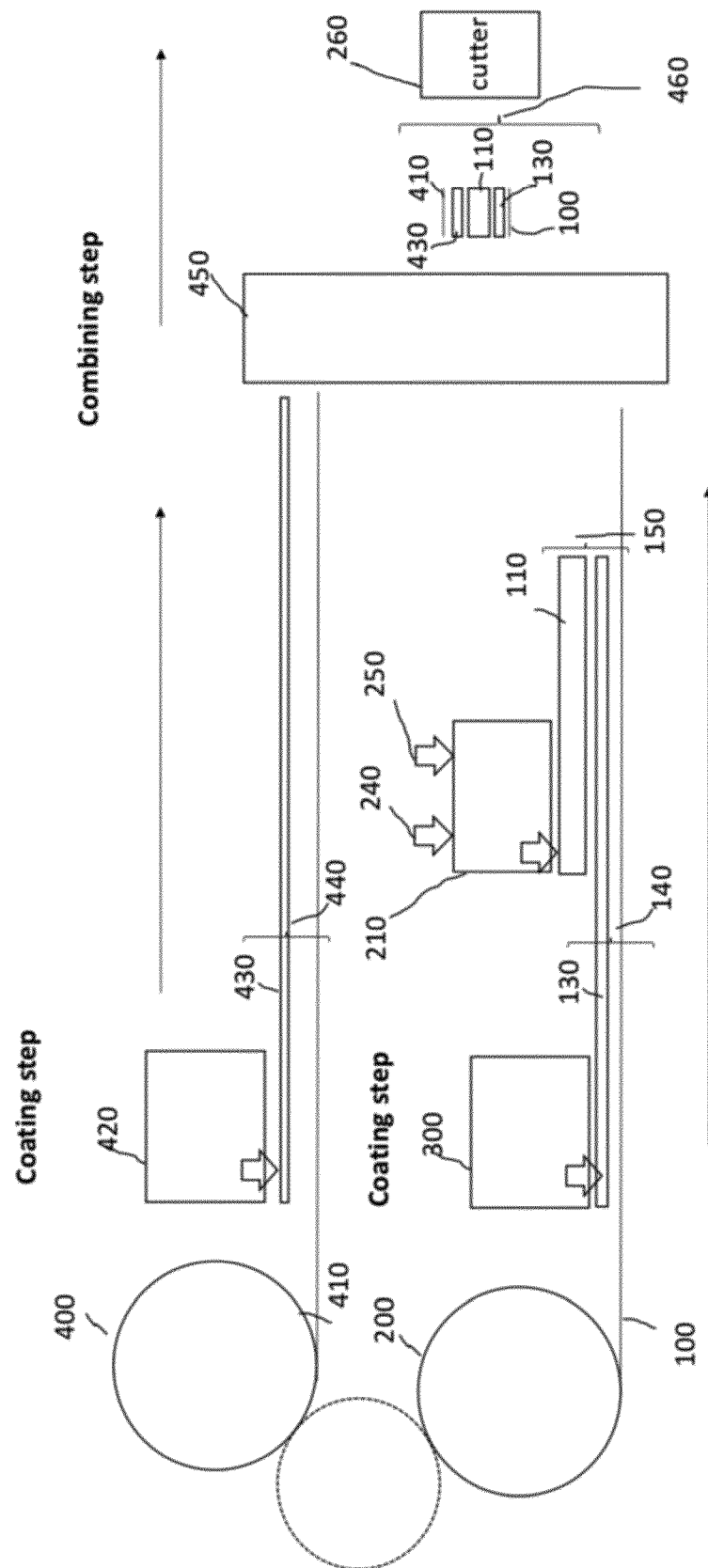


Fig. 5

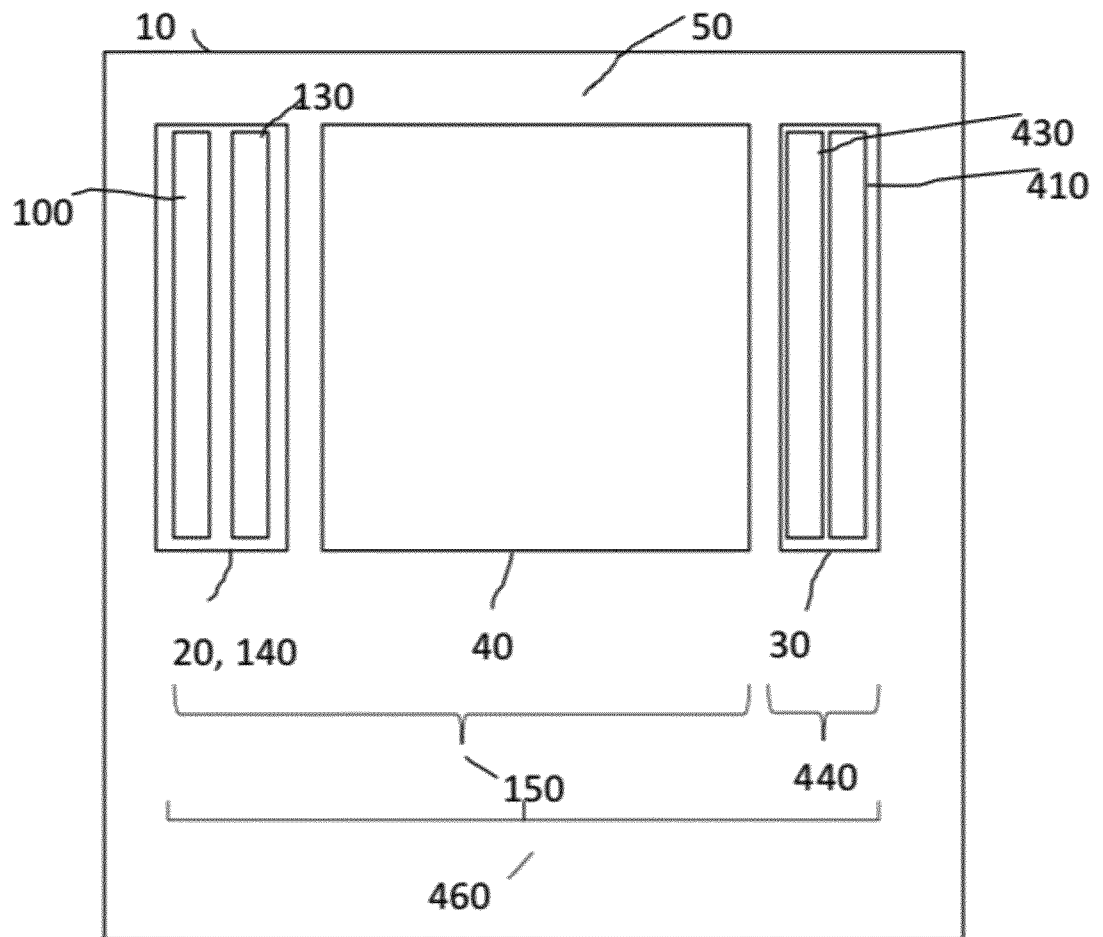


Fig. 6

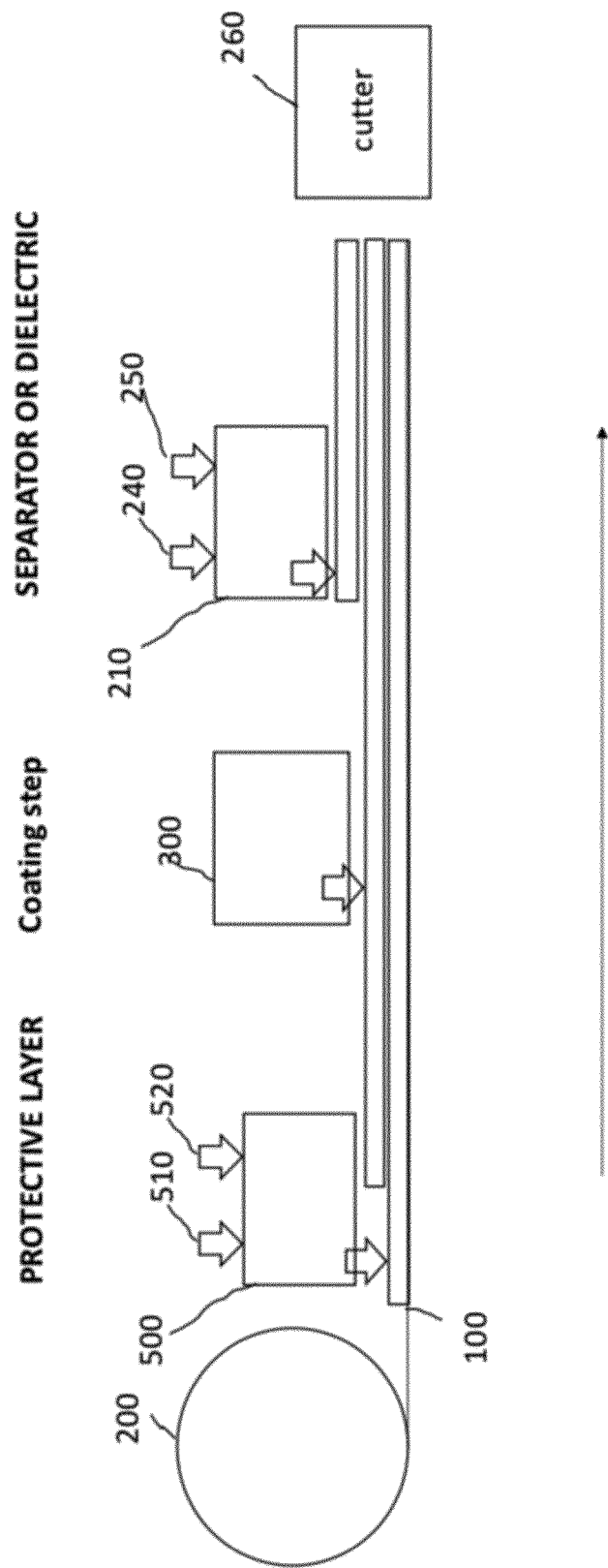


Fig. 7

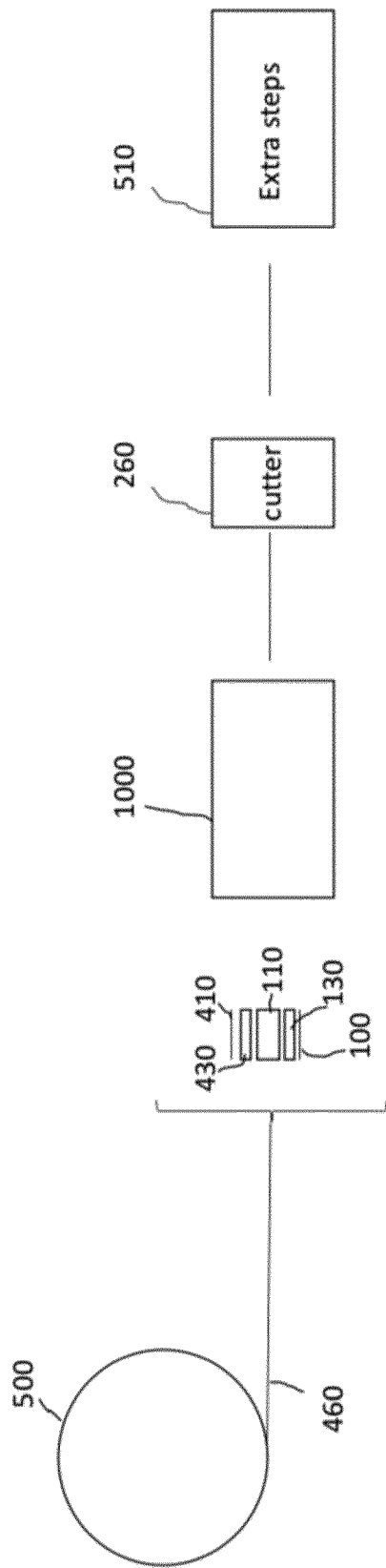


Fig. 8

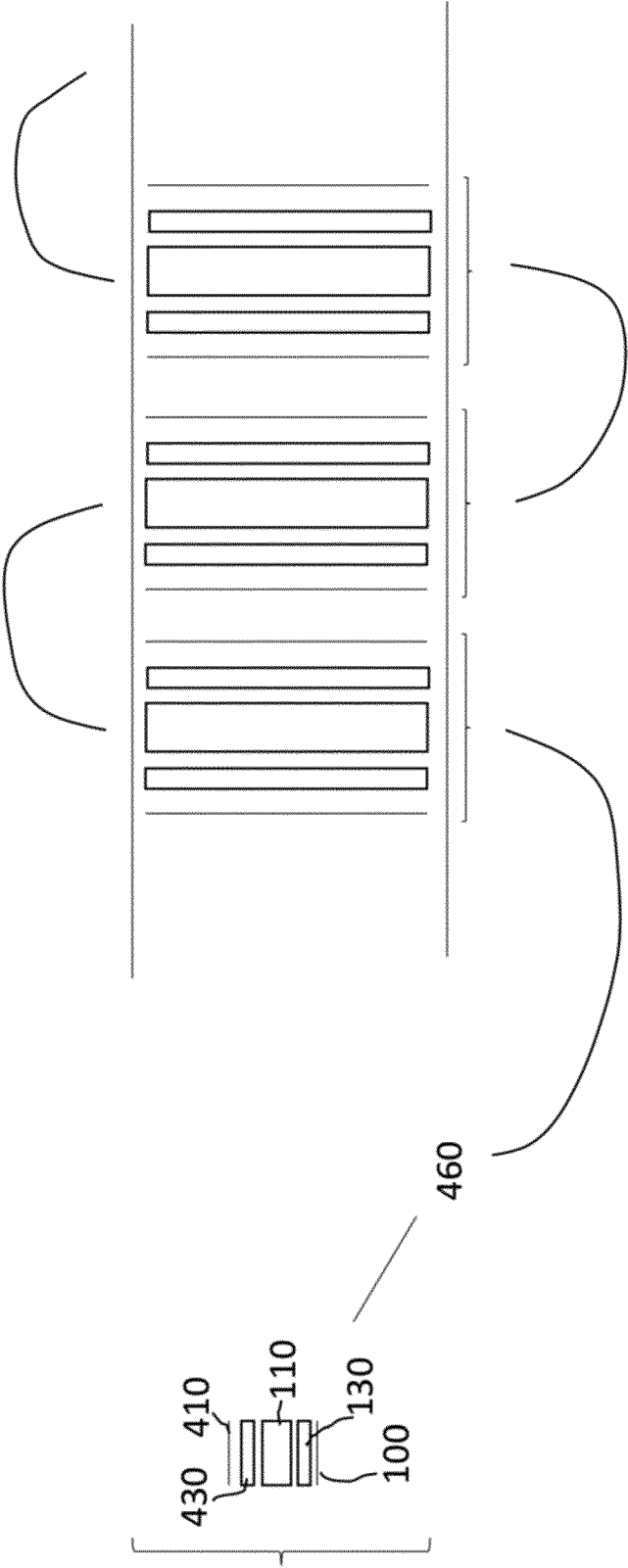


Fig. 9

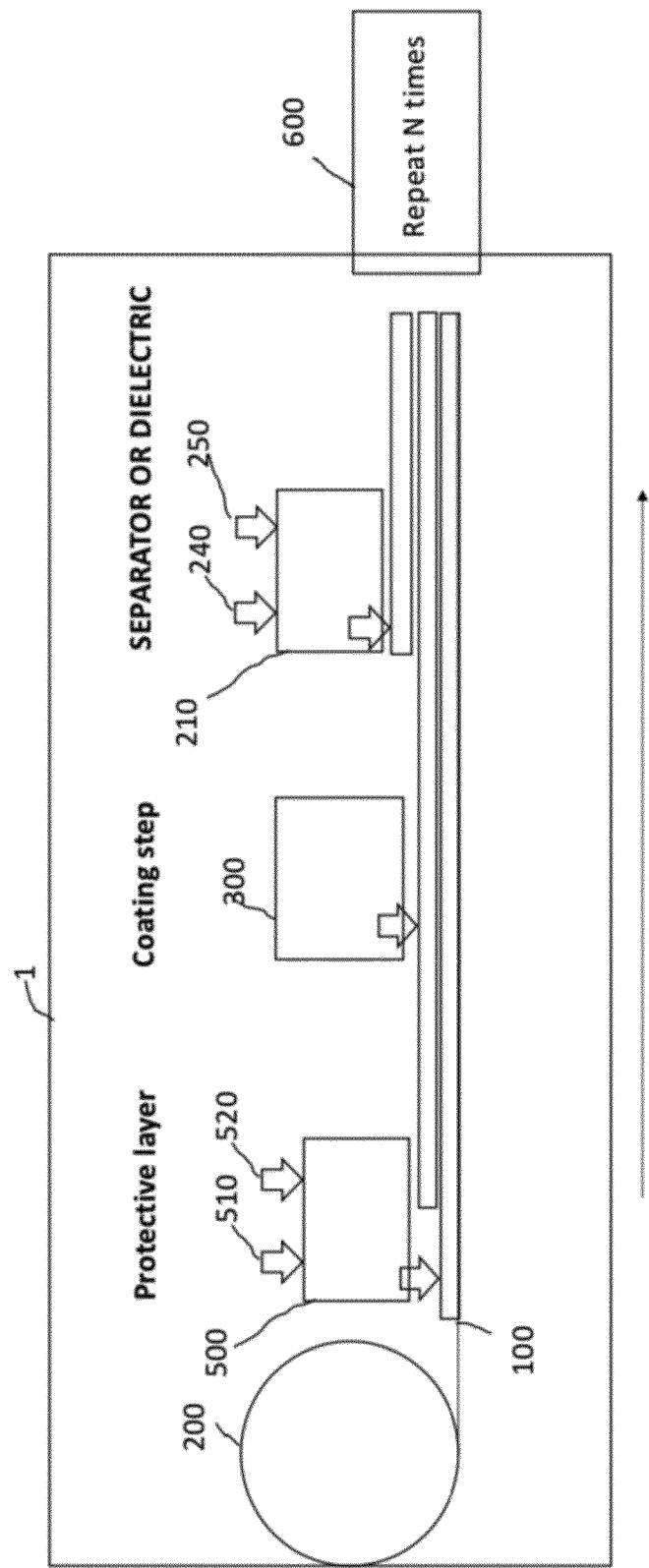


Fig. 10

Re-cycled Paper or Plastics	Al (30nm)	TiN				Slurry	Foam	Slurry	Al (30nm)	Re-cycled Paper or Plastics	TiN	Al (30nm)	Re-cycled Paper or Plastics
Rough and cheap	Conductor and leakage barrier	Conductor and resistorant				Slurry	Foam	Slurry	Conductor and leakage barrier	Rough and cheap	Conductor and resistorant	Conductor and leakage barrier	Rough and cheap

11

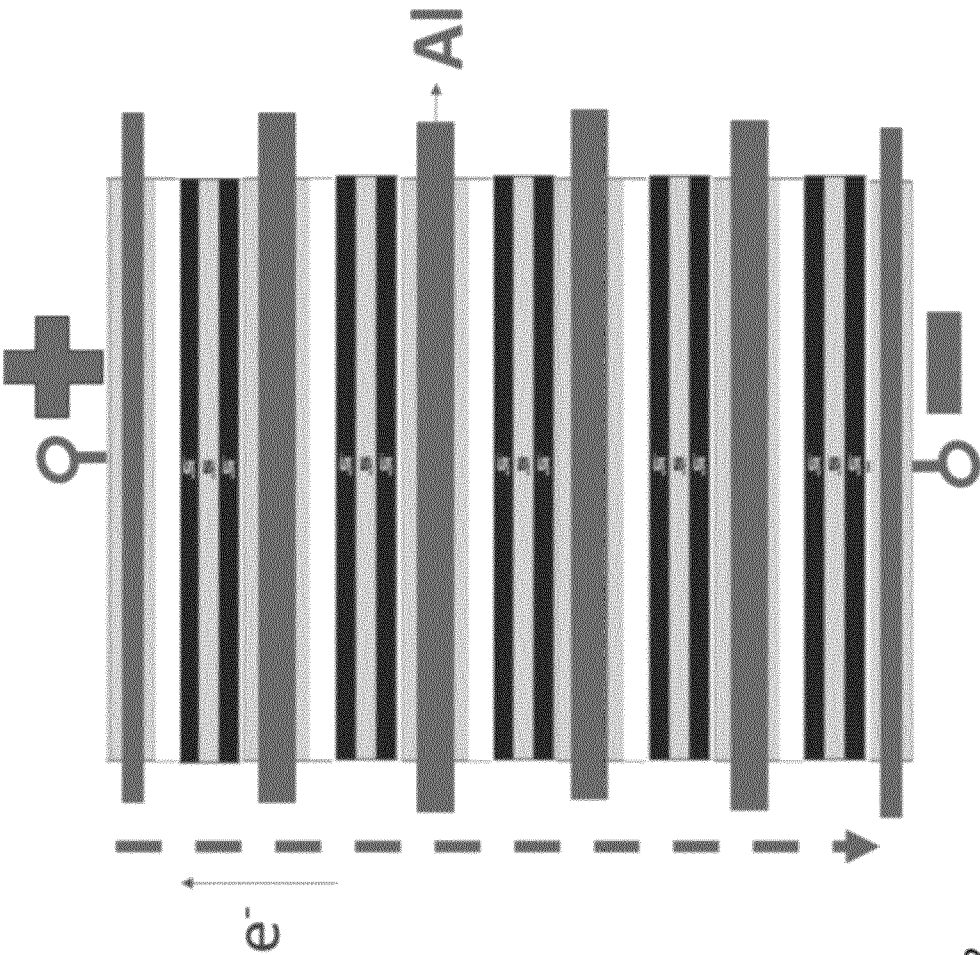
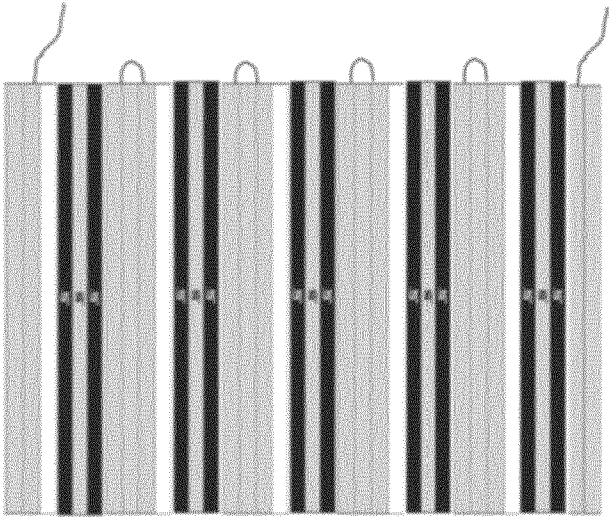


Fig. 12



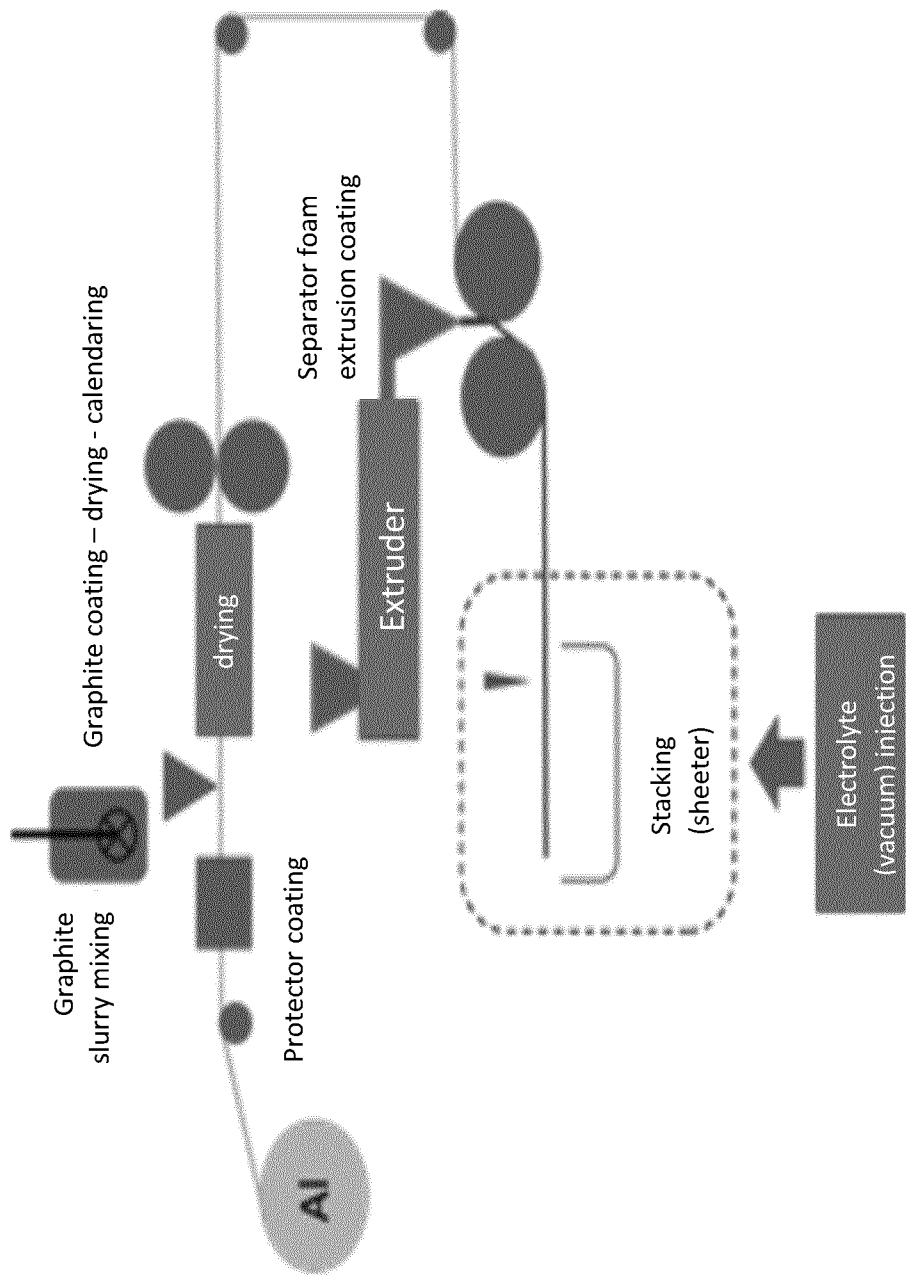


Fig. 13

Re-cycled Paper or Plastics	Al (12µm)	Slurry	Foam	Slurry	TiN Protect or	Al (12µm) Common current collector or	Slurry	Foam	Slurry	TiN Protect or	Al (12µm)	Re-cycled Paper or Plastics
Rough and cheap	Conductor and leakage barrier				Conductor and resistant	Conductor and leakage barrier				Conductor and resistant	Conductor and leakage barrier	Rough and cheap

Fig. 14

