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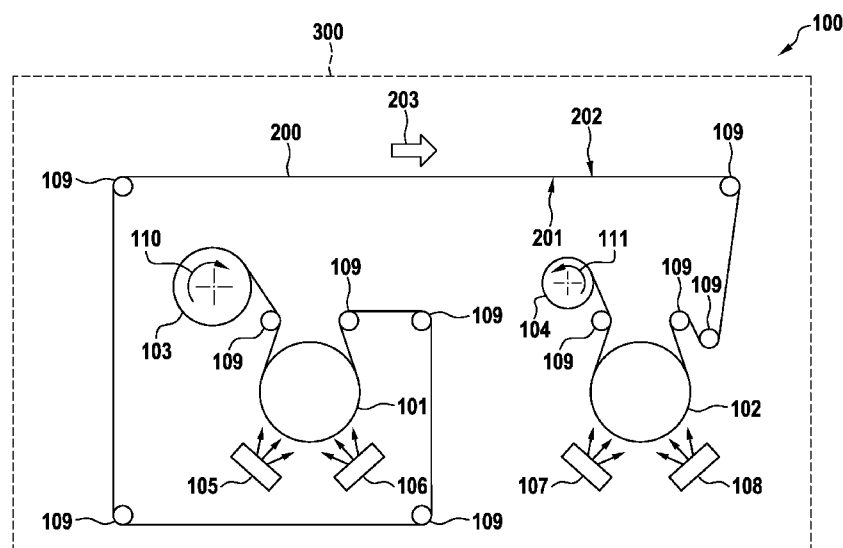
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(54) Title: METHOD OF MANUFACTURING A BATTERY, VACUUM PROCESSING APPARATUS AND BATTERY

Fig. 4



(57) Abstract: The present disclosure provides a method of manufacturing a battery. The method includes providing a separator film, processing the separator film by at least two of the actions of depositing an anode material layer onto a first side of the separator film, depositing a cathode material layer onto a second side of the separator film opposite to the first side, coating the anode material layer with an anode contact, and coating the cathode material layer with an anode contact. At least two of these actions are carried out without a break in vacuum in the vacuum processing environment.

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METHOD OF MANUFACTURING A BATTERY, VACUUM PROCESSING APPARATUS AND BATTERY

TECHNICAL FIELD

[0001] Embodiments of the present disclosure relate to the field of vacuum deposition, and in particular relate to a method of manufacturing battery cells. Furthermore, embodiments of the present disclosure relate to a vacuum processing apparatus adapted for coating a thin separator film. Moreover, embodiments of the present disclosure relate to a battery, the material layers of which are deposited by means of a vacuum processing apparatus.

BACKGROUND

[0002] Batteries or battery cells can be designed for high energy densities and low consumption of mounting space within electronic devices being powered by the battery. Lithium ion battery design is used in many portable devices having high power requirements, e.g. in electric vehicles.

[0003] Battery cells such as lithium ion batteries are manufactured by pasting and/or mixing different materials together for the cathode and the anode. Anode material is coated onto a metal substrate, e.g. an aluminium foil. Meanwhile, cathode material is coated, in a separate process, onto a copper foil. After the two coating processes have been performed, cathode and anode are dried and proceed to the next phase of the manufacture process in which cathode and anode are actioncalendared. Yet another processing action is required for winding cathode and anode together such that a separator film can be placed inbetween.

[0004] Today's manufacturing technology for batteries is based on a variety of processing actions, wherein some of these actions are performed in an atmospheric

environment, and other actions require vacuum processing. A large number of diverse processing actions is both error-prone and cost-intensive.

[0005] In view of the above, there an improvement would be beneficial.

SUMMARY

[0006] In view of the above, the present disclosure provides the following.

[0007] According to an aspect, a method of manufacturing a battery is provided. The manufacturing method includes providing a separator film, processing the separator film in a vacuum processing environment using at least two of the actions of depositing an anode material layer onto a first side of the separator film, depositing a cathode material layer onto a second side of the separator film opposite to the first side, coating the anode material layer with an anode contact, and coating the cathode material layer with a cathode contact. At least two of the above processing actions are carried out without a break in vacuum in the vacuum processing environment.

[0008] According to another aspect, a vacuum processing apparatus adapted for processing a separator film is provided. The vacuum processing apparatus includes a first coating drum having at least one associated first side coating source, the first side coating source being adapted for processing a first side of the separator film, and at least one second coating drum having at least one associated second side coating source, the second side coating source being adapted for processing a second side of the separator film. The first coating drum and the at least one second coating drum are arranged in a common vacuum processing environment.

[0009] According to yet another aspect, a battery manufactured by a method performed in a vacuum processing environment is provided. The battery includes a separator film, an anode material layer deposited onto the first side of the separator film, a cathode material layer deposited onto the second side of the separator film opposite to

- 3 -

the first side, an anode contact coated onto the anode material layer, and a cathode contact coated onto the cathode material layer.

[0010] The feature that at least two of the processing actions are carried out without a break in vacuum in the vacuum processing environment can typically be understood in that the processing actions take place at the same time.

[0011] Further embodiments, aspects, details and advantages are evident from the dependent claims, the description, and the drawings. Those skilled in the art will recognize additional features and advantages upon reading the following detailed description, and upon viewing the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The components in the figures are not necessarily true to scale, instead emphasis is placed upon illustrating the principles of the invention. Moreover, in the figures, like reference numerals designate corresponding parts. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

[0013] Figure 1 illustrates a schematic block diagram of a vacuum processing apparatus adapted for processing a separator film, according to an embodiment;

[0014] Figure 2 illustrates a schematic block diagram of a vacuum processing apparatus adapted for processing a separator film, according to another embodiment;

[0015] Figure 3 illustrates a schematic block diagram of a vacuum processing apparatus adapted for processing a separator film, according to yet another embodiment;

[0016] Figure 4 illustrates a schematic block diagram of a vacuum processing apparatus adapted for processing a separator film, according to yet another embodiment;

[0017] Figure 5 is a flowchart for illustrating a method of manufacturing a battery having a separator film, according to an embodiment; and

[0018] Figure 6 is an illustration of layers of a battery manufactured by a method illustrated in Figure 5, according to an embodiment.

DETAILED DESCRIPTION

[0019] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof, and in which specific embodiments are shown by way of illustration. In this regard, directional terminology, such as "horizontal", "vertical", "front", "back", etc., is used with reference to the orientation of the figure(s) being described. Because components of embodiments can be positioned in a number of different orientations, the directional terminology is used for purpose of illustration and is in no way limiting. It is to be understood that other embodiments can be utilized and structural or logical changes can be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims. The embodiments being described use specific language, which should not be construed as limiting the scope of the appended claims.

[0020] Reference will now be made in detail to various embodiments, one or more examples of which are illustrated in the figures. Each example is provided by way of explanation, and is not meant as a limitation of the invention. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the present invention includes such modifications and variations. The examples are described using specific language which should not be construed as limiting the scope of the appending

claims. The drawings are not to scale and are for illustrative purposes only. For clarity, the same elements or manufacturing actions have been designated by the same references in the different drawings if not stated otherwise.

[0021] As used herein, the term “vacuum processing environment” should be understood as describing a low-pressure environment where a thin film can be processed by appropriate processing sources. As used herein, the term “vacuum break” should be understood as describing a process where components to be processed in a vacuum environment are exposed to an ambient, or different, atmosphere or processing environment between successive processing actions.

[0022] According to aspects, the present disclosure proposes a method of manufacturing a battery, wherein the method includes providing a separator film, and processing the separator film using at least two of the actions of (a) depositing an anode material layer onto a first side of the separator film, (b) depositing a cathode material layer onto a second side of the separator film opposite to the first side, (c) coating the anode material layer with an anode contact, and (d) coating the cathode material layer with a cathode contact.

[0023] According to embodiments described herein, at least two of the above processing actions (a) to (d) are carried out without a break in vacuum in the vacuum processing environment. For example, actions (c) and (d) can be performed in a different processing environment, after actions (a) and (b) have been performed in a common processing environment.

[0024] Moreover, according to yet other aspects, the present disclosure proposes a vacuum processing apparatus adapted for processing a separator film. The vacuum processing apparatus includes a first coating drum having at least one associated first side coating source, the first side coating source being adapted for processing a first side of the separator film, and at least one second coating drum having at least one associated second side coating source, the second side coating source being adapted

for processing a second side of the separator film. The first coating drum and the at least one second coating drum are arranged in a common vacuum processing environment.

[0025] Furthermore, the present disclosure relates to a battery manufactured by a method performed completely in a single, or common, vacuum processing environment. The battery includes a separator film, an anode material layer deposited onto the first side of the separator film, a cathode material layer deposited onto the second side of the separator film opposite to the first side, an anode contact coated onto the anode material layer, and a cathode contact coated onto the cathode material layer. The battery is produced with the method as described herein. In particular, the battery may be produced by use of the vacuum processing apparatus as described herein.

[0026] Figure 1 illustrates a schematic block diagram of a vacuum processing apparatus 100 adapted for processing a separator film 200, according to an embodiment. As shown in Figure 1, a reference numeral 300 denotes a common vacuum processing environment in which some or all of the processing actions of manufacturing a battery can be performed. The separator film 200 may be provided on an unwinder 103 which rotates in the direction of an arrow 110 when the separator film is being delivered. Furthermore, the separator film 200 may be guided over at least one guide roller 109 towards a first coating drum 101. By passing around the first coating drum 101, the separator film 200 can be processed at a first side 201, or at the front side, of the separator film 200. Processing may be performed by at least one first-side coating source 105, where, for example, an anode material layer may be deposited onto the first side 201 of the separator film 200.

[0027] According to an embodiment which can be combined with other embodiments described herein, both the unwinder 103 adapted for unwinding the separator film 200 and a rewinder 104 adapted for winding up or rewinding the processed separator film 200 can be arranged in the common vacuum processing environment 300. Thereby, any vacuum break between successive processing actions can be avoided.

[0028] It is noted here, that the separator film 200 may be provided as a substrate which can act as an ion barrier. More specifically, a separator film may particularly be a permeable membrane film suitable for placing it between a battery's anode and cathode. The function of the separator film is typically to keep the two electrodes apart to prevent electrical short circuits while also allowing the transport of ionic charge carriers that are needed to close the circuit during the passage of current in the battery. For instance, a separator film may be a thermoplastic polymer, such as PET (Polyethylene terephthalate) or PP (polypropylen). The thickness of the separator film may be between 8 μm and 100 μm)

[0029] According to embodiments which can be combined with other embodiments described herein, the at least one first-side coating source 105 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0030] The separator film 200 which has been processed at its first side 201 may be guided via further guide rollers 109, in a transport direction 203, towards a second coating drum 102. As an example, the separator film 200 is transported in an approximately horizontal direction from one portion of the vacuum processing apparatus 100 where the first coating drum 101 is located, to another portion of the vacuum processing apparatus 100, where the second coating drum 102 is located. According to an embodiment, the two portions of the vacuum processing apparatus 100 are located in the common vacuum processing environment 300. As in the case of the first coating drum 101, at least one second-side coating source 107 associated with the second coating drum 102 may be provided. Thereby, the second-side coating source 107 can be used for processing the second side 202 - or back side - of the separator film 200. Processing of the second side 202 of the separator film 200 can include depositing a cathode material layer onto the separator film 200.

[0031] As can be seen in the illustrative block diagram of Figure 1 showing the vacuum processing apparatus 100 according to an embodiment, the separator film 200

may be guided from the first coating drum 101 to the second coating drum 102 such that now a different side 202, namely the back side, of the separator film 200 is processed at the second coating drum 102. In other words, the first-side coating source 105 can be used for processing the first side 201 or front side of the separator film 200, and the second-side coating source 107 can be used for processing the second side 202 or back side of the separator film 200. Thus, double-sided coating of the separator film 200 can be carried out in the common vacuum processing environment 300. The processing actions for processing of the separator film 200 can be performed without any break in vacuum between successive processing actions.

[0032] The separator film 200 may then be guided over an additional guide roller 109 towards the rewinder 104 rotating in a direction of arrow 111. The processed separator film 200 may be wound up at the rewinder 104 and can be removed from the vacuum processing environment 300 for further use.

[0033] According to embodiments which can be combined with other embodiments described herein, the at least one second-side coating source 107 associated with the second-side coating drum 102 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0034] It is noted here, although not depicted in the drawings that a variable number of coating sources can be located within the common vacuum processing environment 300. In this way, a variety of deposition processes can be performed in the common vacuum processing environment 300 without a break in vacuum. In particular, it is possible to process anode and cathode components in a single action in order to manufacture the battery.

[0035] Figure 2 illustrates a schematic block diagram of a vacuum processing apparatus 100 adapted for processing the separator film 200, according to another embodiment. Within the common vacuum processing environment 300, the processing

actions of manufacturing the battery can be performed. The separator film 200 is provided on the unwinder 103 which rotates in the direction of the arrow 110 when the separator film 200 is being delivered. Furthermore, the separator film 200 may be guided over the at least one guide roller 109 towards the first coating drum 101. By passing around the first coating drum 101, the first side 201 of the separator film 200 can be treated.

[0036] In the vacuum processing apparatus 100 shown in Figure 2, processing of the first side 201 is performed by two different first-side coating sources 105 and 106. According to embodiments which can be combined with other embodiments described herein, one or both of the one first-side coating sources 105, 106 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof. Processing can be performed by one first-side coating source 105, where, for example, an anode material layer is deposited onto the first side 201 of the separator film 200. Then, the separator film 200 advances and passes the other first-side coating source 106, where, for example, the anode material layer is coated with an anode contact.

[0037] Then, the separator film 200 which has been processed at its first side 201 may be guided via further guide rollers 109, in the transport direction 203, towards the second coating drum 102. At the second coating drum 102 processing of the second side 202 of the separator film 200 may be performed in a way similar to that which already has been described herein with respect to Figure 1. As in the case of the first coating drum 101, the second-side coating source 107 may be associated with the second coating drum 102. Processing of the second side 202 of the separator film 200 can include depositing a cathode material layer onto the separator film 200.

[0038] As can be seen in the illustrative block diagram of Figure 2 showing the vacuum processing apparatus 100 according to an embodiment, the separator film 200 is guided from the first coating drum 101 to the second coating drum 102 such that now a different side 202, namely the back side, of the separator film 200 may be processed

at the second coating drum 102. In other words, first-side coating sources 105, 106 can be used for processing the first side 201 or front side of the separator film 200, wherein the second-side coating source 107 can be used for processing the second side 202 or back side of the separator film 200. Thus, double-sided coating of the separator film 200 can be carried out in the common vacuum processing environment 300. In this way, the processing actions for processing of the separator film 200 can be performed without any vacuum break between successive processing actions.

[0039] Again, the separator film 200 is guided over an additional guide roller 109 towards the rewinder 104 rotating in a direction of arrow 111. The processed separator film 200 is wound up at the rewinder 104 and can be removed from the vacuum processing environment 300 for further use. It is noted here, although not depicted in the drawings, that a variable number of coating sources can be located within the common vacuum processing environment 300. In this way, a variety of deposition processes can be performed in the common vacuum processing environment 300 without a break in vacuum.

[0040] Figure 3 illustrates a schematic block diagram of a vacuum processing apparatus 100 adapted for processing the separator film 200, according to embodiments. As depicted in Figure 3, two separate vacuum processing environments may be provided, i.e. a first vacuum processing environment 301 and a second vacuum processing environment 302. The two vacuum processing environments 301, 302 may be adjacent to each other and are interconnected via a vacuum lock 303, through which the separator film 200 can pass in a transport direction 203. In the first vacuum processing environment 301 the first side 201 of the separator film 200 can be processed, wherein the second side 202 of the separator film 200 can be processed in the second vacuum processing environment 302.

[0041] Within each vacuum processing environment 301, 302 different processing actions of manufacturing the battery can be performed without a break in vacuum, respectively. Again, the separator film 200 may be provided on the unwinder 103 located

in the first vacuum processing environment and rotating in the direction of the arrow 110 when the separator film 200 is being delivered. Furthermore, the separator film 200 is guided over the at least one guide roller 109 towards the first coating drum 101. By passing around the first coating drum 101 the first side 201 of the separator film 200 can be treated. As depicted in Figure 3, processing of the first side 201 may be performed by two different first-side coating sources 105 and 106.

[0042] According to embodiments which can be combined with other embodiments described herein, one or both of the one first-side coating sources 105, 106 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof. Processing can be performed by one first-side coating source 105, where, for example, an anode material layer is deposited onto the first side 201 of the separator film 200. Then, the separator film 200 advances and passes the other first-side coating source 106, where, for example, the anode material layer may be coated with an anode contact.

[0043] Then, the separator film 200 which has been processed at its first side 201 may be guided via further guide rollers 109, in the transport direction 203, from the first vacuum processing environment 301 to the second vacuum processing environment 302. The separator film 200 may pass through the vacuum lock 303 towards the second coating drum 102. As depicted in Figure 3, processing of the second side 202 may be performed by two different second-side coating sources 107 and 108. According to embodiments which can be combined with other embodiments described herein, one or both of the one second-side coating sources 107, 108 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0044] Processing can be performed by one second-side coating source 107, where, for example, a cathode material layer is deposited onto the second side 202 of the separator film 200 opposite to the first side 201. Then, the separator film 200 may further

advance and pass the other second-side coating source 106, where, for example, the cathode material layer is coated with a cathode contact.

[0045] As can be seen in the illustrative block diagram of Figure 3 showing the vacuum processing apparatus 100 according to an embodiment, the separator film 200 may be guided from the first coating drum 101 to the second coating drum 102 such that two opposite sides 201, 202 of the separator film 200 can be processed and a double-sided coating of the separator film 200 can be performed. According to the vacuum processing apparatus 100 shown in Figure 3, the processing actions for processing the first side 201 of the separator film 200 can be performed in a common, first vacuum processing environment 301 without vacuum break. On the other hand, processing of the second side 202 of the separator film 200 can be performed in a common, second vacuum processing environment 302 without a break in vacuum. In this way, successive processing actions for processing of the first side 201 and second side 202, respectively, of the separator film 200 can be performed without a break in vacuum. The separator film 200 may then be guided over an additional guide roller 109 towards the rewinder 104 located in the second vacuum processing environment 302. The processed separator film 200 may be wound up at the rewinder 104 and can be removed from the second vacuum processing environment 302 for further use.

[0046] Figure 4 illustrates a schematic block diagram of a vacuum processing apparatus 100 adapted for processing a separator film 200, according to yet another embodiment. Again, a reference numeral 300 denotes the common vacuum processing environment in which four processing actions of manufacturing a battery can be performed. As before, the separator film 200 may be provided on the unwinder 103 rotating in the direction of the arrow 110 when the separator film is being delivered. Furthermore, the separator film 200 may be guided over at least one guide roller 109 towards the first coating drum 101. By passing around the first coating drum 101, the separator film 200 may be processed at its first side 201, or front side. Processing may be performed by at least one first-side coating source 105, 106. According to an embodiment which can be combined with other embodiments described herein, both the

unwinder 103 adapted for unwinding the separator film 200 and the rewinder 104 adapted for winding up or rewinding the processed separator film 200 can be arranged in the common vacuum processing environment 300. Thereby, any vacuum break between successive processing actions can be avoided.

[0047] According to embodiments which can be combined with other embodiments described herein, the two first-side coating sources 105, 106 shown in Figure 4 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof. Processing can be performed by one first-side coating source 105, where, for example, an anode material layer is deposited onto the first side 201 of the separator film 200. Then, the separator film 200 further may advance and pass the other first-side coating source 106, where, for example, the anode material layer is coated with an anode contact.

[0048] Then, the separator film 200 which has been processed at its first side 201 may be guided via further guide rollers 109, in the transport direction 203, towards a second coating drum 102. As an example, the separator film 200 is transported in an approximately horizontal direction from one portion of the vacuum processing apparatus 100 where the first coating drum 101 is located, to another portion of the vacuum processing apparatus 100, where the second coating drum 102 is located. According to an embodiment, the two portions of the vacuum processing apparatus 100 are located in the common vacuum processing environment 300. As in the case of the first coating drum 101, coating sources 107, 108 may be associated with the second coating drum 102. Thus, at least one second-side coating source 107, 108 may be used for processing the second side 202 of the separator film 200 passing by. According to embodiments which can be combined with other embodiments described herein, one or both of the one second-side coating sources 107, 108 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0049] Processing can be performed by one second-side coating source 107, where, for example, a cathode material layer is deposited onto the second side 202 of the separator film 200 opposite to the first side 201. Then, the separator film 200 may further advance and pass the other second-side coating source 106, where, for example, the cathode material layer is coated with a cathode contact.

[0050] As can be seen in the illustrative block diagram of Figure 4 showing the vacuum processing apparatus 100 according to an embodiment, the separator film 200 is guided from the first coating drum 101 to the second coating drum 102 such that now a different side 202, i.e. the back side, of the separator film 200 is processed at the second coating drum 102. In other words, first-side coating sources 105, 106 can be used for processing the first side 201 or front side of the separator film 200, wherein the second-side coating sources 107, 108 can be used for processing the second side 202 or back side of the separator film 200, respectively. Thereby, double-sided coating of the separator film 200 can be carried out in the common vacuum processing environment 300. In this way, the processing actions for processing of the separator film 200 can be performed without any vacuum break between successive processing actions.

[0051] The separator film 200 may be then guided over an additional guide roller 109 towards the rewinder 104 rotating in a direction of arrow 111. The processed separator film 200 may be wound up at the rewinder 104 and can be removed from the vacuum processing environment 300 for further use.

[0052] According to embodiments which can be combined with other embodiments described herein, the at least one second-side coating source 107, 108 associated with the second-side coating drum 102 can be selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0053] It is noted here, although not depicted in the drawings, that a variable number of coating sources can be located within the common vacuum processing environment

300. In this way, a variety of deposition processes can be performed in the common vacuum processing environment 300 without a break in vacuum. In particular, it is possible to process anode and cathode components in a single action in order to obtain the battery. Absence of a vacuum break during processing of the separator film 200 can result in a reduction of oxidation of coated materials such that no additional film or interleaves are required for covering and protecting coated materials.

[0054] In this way, a vacuum processing apparatus 100 can be obtained, which includes the first coating drum 101 having at least one associated first side coating source 105, 106, the first side coating source 105, 106 being adapted for processing the first side 201 of the separator film 200, and at least one second coating drum 102 having at least one associated second side coating source 107, 108, the second-side coating sources 107, 108 being adapted for processing the second side 202 of the separator film 200. In particular, the first coating drum 101 together with its associated coating sources 105, 106 and the at least one second coating drum 102 together with its associated coating sources 107, 108 are arranged in the common vacuum processing environment 300, such that a break in vacuum can be avoided.

[0055] Figure 5 is a flowchart for illustrating a method of manufacturing a battery having a separator film, according to an embodiment. The procedure starts at a block 401. Then, at a block 402, the separator film 200 is provided. The separator film 200 is then processed using at least two of the following actions (a) to (d):

- a) depositing an anode material layer onto a first side of the separator film, block 403a;
- b) depositing a cathode material layer onto a second side of the separator film opposite to the first side, block 403b;
- c) coating the anode material layer with an anode contact, block 403c; and
- d) coating the cathode material layer with a cathode contact, block 403d.

[0056] At a block 404, the procedure may be ended. The processed separator film with the anode material layer, the cathode material layer, the anode contact and the cathode contact deposited thereon can then be wound up to form the battery.

[0057] According to embodiments described herein, at least two of the above processing actions (a) to (d) are carried out without a break in vacuum, i.e. in a common vacuum processing environment. For example, actions (c) and (d) can be performed in a different processing environment, after actions (a) and (b) have been performed in the common vacuum processing environment, or vice versa.

[0058] According to an embodiment which can be combined with other embodiments described herein, the separator film 200 can be provided in a roll-to-roll arrangement, the components of the roll-to-roll arrangement being arranged within the common vacuum processing environment 300. In particular, the separator film 200 can be guided over the first coating drum 101 having at least one associated first side coating source 105, 106 for processing the first side 201 of the separator film 200. Furthermore, the separator film 200 can be guided over the second coating drum 102 having at least one associated second side coating source 107, 108 for processing the second side 202 of the separator film 200 within the common vacuum processing environment 300, such that double-sided processing of the separator film 200 can be performed without a break in vacuum.

[0059] Thereby, depositing a material layer onto one of the first side 201 and the second side 202 of the separator film 200 can be performed by a variety of vacuum deposition processes. According to embodiments, which can be combined with other embodiments described herein, depositing the material layer onto one of the first side 201 and the second side 202 of the separator film 200 can be performed by at least one coating source 105, 106, 107, 108 selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

[0060] Figure 6 is a schematic illustration of layers of a battery 208 manufactured by a method illustrated in Figure 5, according to an embodiment. As shown in Figure 6, different layers may be deposited on either side of the separator film 200. It is noted here, although not shown in the drawings, that forming a battery 208 according to embodiments described herein can include winding up the processed separator film 200 together with the deposited layers. As shown, processing of the separator film 200 at its first side 201 has been performed by at least one first-side coating source 105, wherein the anode material layer 205 has been deposited onto the first side 201.

[0061] According to an embodiment which can be combined with other embodiments described herein, depositing the anode material layer onto the first side 201 of the separator film 200 opposite to the second side 202 can include depositing a negative active material selected from the group consisting of carbon, graphite, PVdF, Si-based material, metal-anode material, and any combination thereof.

[0062] By this point, the separator film 200 has been advanced in the transport direction 203 such that it has passed another first-side coating source 106, where the anode material layer 205 has been coated with the anode contact 206.

[0063] Furthermore, processing of the separator film 200 at its second side 202 has been performed by at least one second-side coating source 107, wherein the cathode material layer 204 has been deposited onto the second side 202 of the separator film 200.

[0064] According to an embodiment which can be combined with other embodiments described herein, depositing the cathode material layer onto the second side 202 of the separator film 200 can include depositing a positive active material selected from the group consisting of Li metal, Li oxide, copper, LiCoO_2 , $\text{LiN}_x\text{Co}_{1-x}\text{O}_2$, LiMn_2O_4 , PVdF, LiFePO_4 , and any combination thereof.

[0065] By this point, the separator film 200 has been advanced in the transport direction 203 such that it passed another second-side coating source 108, where the cathode material layer 204 has been coated with the cathode contact 207.

[0066] It is noted here, that in embodiments it is desirable that shrinkage of the separator film 200 is reduced or avoided. In particular, regarding a battery, a deformation or shrinkage of the separator film 200 can be deleterious because shrinkage of the separator film can result in a contact or a short circuit between an anode material layer and a cathode material layer. Shrinkage of the separator film 200 can particularly be avoided or at least reduced by an appropriate selection of materials and/or processing actions.

[0067] According to another embodiment, which can be combined with other embodiments described herein, processing of the separator film 200 can further include providing a shrinkage-reducing layer adapted for reducing shrinkage of the separator film 200. According to a modification thereof, the shrinkage-reducing layer can be provided as an Al_2O_3 coating. Furthermore, a material for the shrinkage-layer can be selected from the group consisting of Al_2O_3 , AlO_x , ceramics, and any combination thereof. In this way, shrinkage of the separator film 200 during processing actions within the common vacuum processing environment 300 can be avoided or at least reduced, and, in addition to that, battery performance may be improved. The shrinkage reducing layer, such as the Al_2O_3 layer, may be provided as a layer with a thickness of between 50 nm and 300 nm.

[0068] In order to protect the material layers and/or contacts deposited onto the separator film 200, according to yet another modification, at least one protective layer can be deposited onto at least one of the anode contact and the cathode contact.

[0069] In this way, a battery may be manufactured, the battery including a separator film 200, an anode material 205 layer deposited onto the first side 201 of the separator film 200, a cathode material layer 204 deposited onto the second side 202 of the

separator film 200 opposite to the first side 201, an anode contact 206 coated onto the anode material layer 205; and a cathode contact 207 coated onto the cathode material layer 204.

[0070] According to an embodiment which can be combined with other embodiments described herein, the battery manufactured according to methods described herein can have a layer thickness of the anode material layer 205 and/or the cathode material layer 204 which is in a range from 1 μm to 100 μm , preferably in a range from 2 μm to 20 μm , and more preferably in a range from 3 μm to 15 μm . Thereby, very thin and light battery cells can be manufactured. In this way, batteries or battery cells can be obtained which provide a high energy density and which consume only a small amount of mounting space within electronic devices being powered by the battery.

[0071] While the foregoing is directed to embodiments of the invention, other and further embodiments of the invention can be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. A method of manufacturing a battery, the method comprising:

providing a separator film;

processing the separator film in a vacuum processing environment using at least two of the following actions (a) to (d):

(a) depositing an anode material layer onto a first side of the separator film;

(b) depositing a cathode material layer onto a second side of the separator film opposite to the first side;

(c) coating the anode material layer with an anode contact; and

(d) coating the cathode material layer with a cathode contact,

wherein at least two of the above actions (a) to (d) are carried out without a break in vacuum in the vacuum processing environment.

2. The method according to claim 1, wherein the separator film is delivered in a roll-to-roll arrangement provided within the vacuum processing environment.
3. The method according to claim 1 or 2, wherein the processed separator film is wound up to form the battery.
4. The method according to any one of the preceding claims, wherein

the separator film is guided over a first coating drum having at least one associated first side coating source for processing the first side of the separator film; and

the separator film is guided over a second coating drum having at least one associated second side coating source for processing the second side of the separator film.

5. The method according to any one of the preceding claims, wherein depositing the cathode material layer onto the second side of the separator film comprises depositing a positive active material selected from the group consisting of Li metal, Li oxide, copper, LiCoO_2 , $\text{LiN}_x\text{Co}_{1-x}\text{O}_2$, LiMn_2O_4 , PVdF, LiFePO_4 , and any combination thereof.
6. The method according to any one of the preceding claims, wherein depositing the anode material layer onto the first side of the separator film comprises depositing a negative active material selected from the group consisting of carbon, graphite, PVdF, Si-based material, metal-anode material, and any combination thereof.
7. The method according to any one of the preceding claims, wherein depositing a material layer onto one of the first side and the second side of the separator film is performed by at least one coating source selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.
8. The method according to any one of the preceding claims, wherein processing the separator film further comprises providing a shrinkage-reducing layer adapted for

- 22 -

reducing shrinkage of the separator film, wherein a material for the shrinkage-reducing layer is selected from the group consisting of Al_2O_3 , AlO_x , ceramics, and any combination thereof.

9. The method according to any one of the preceding claims, wherein at least one protective layer is deposited onto at least one of the anode contact and the cathode contact.

10. A vacuum processing apparatus adapted for processing a separator film, the apparatus comprising:

a first coating drum having at least one associated first side coating source, the first side coating source being adapted for processing a first side of the separator film; and

at least one second coating drum having at least one associated second side coating source, the second side coating source being adapted for processing a second side of the separator film,

wherein the first coating drum and the at least one second coating drum are arranged in a common vacuum processing environment.

11. The vacuum processing apparatus according to claim 10, wherein the at least one first side coating source and/or the at least one second side coating source is/are selected from the group consisting of a boat evaporator, an e-beam evaporator, a sputtering cathode, a PVD coating source, a CVD coating source, and any combination thereof.

12. The vacuum processing apparatus according to claim 10 or 11, further comprising an unwinder adapted for unwinding the separator film and a rewinder adapted for winding up the processed separator film.
13. The vacuum processing apparatus according to claim 12, wherein the unwinder and/or the rewinder are arranged in the common vacuum processing environment.
14. A battery manufactured by a method according to any one of the claims 1 to 9, wherein the method has preferably been performed in a vacuum processing apparatus according to any one of the claims 11 to 13, the battery comprising:
- a separator film;
 - an anode material layer deposited onto the first side of the separator film;
 - a cathode material layer deposited onto the second side of the separator film opposite to the first side;
 - an anode contact coated onto the anode material layer; and
 - a cathode contact coated onto the cathode material layer.
15. The battery according to claim 14, wherein a layer thickness of the anode material layer and/or the cathode material layer is in a range from 1 μm to 100 μm , preferably in a range from 2 μm to 20 μm , and more preferably in a range from 3 μm to 15 μm .

Fig. 1

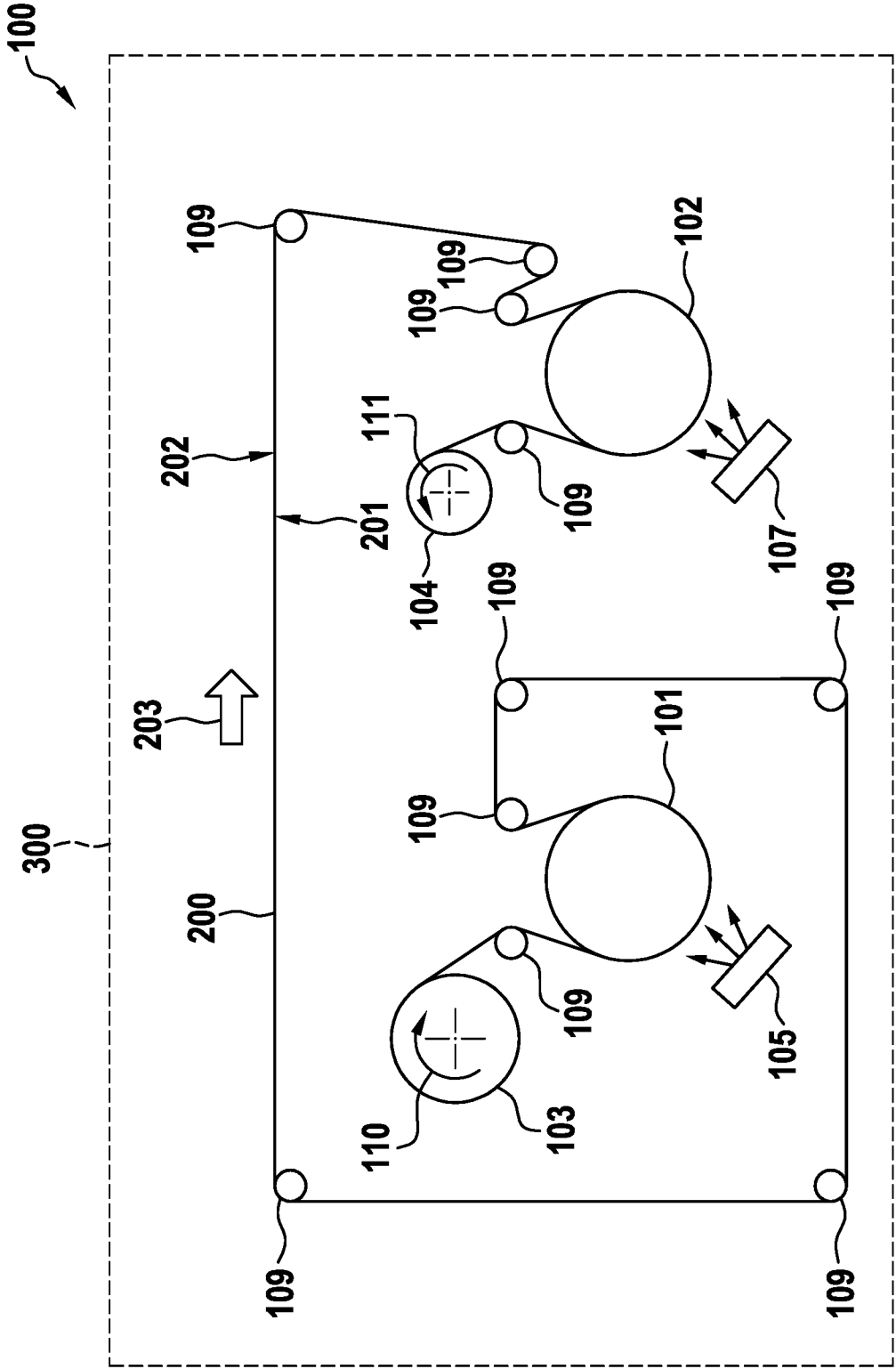


Fig. 2

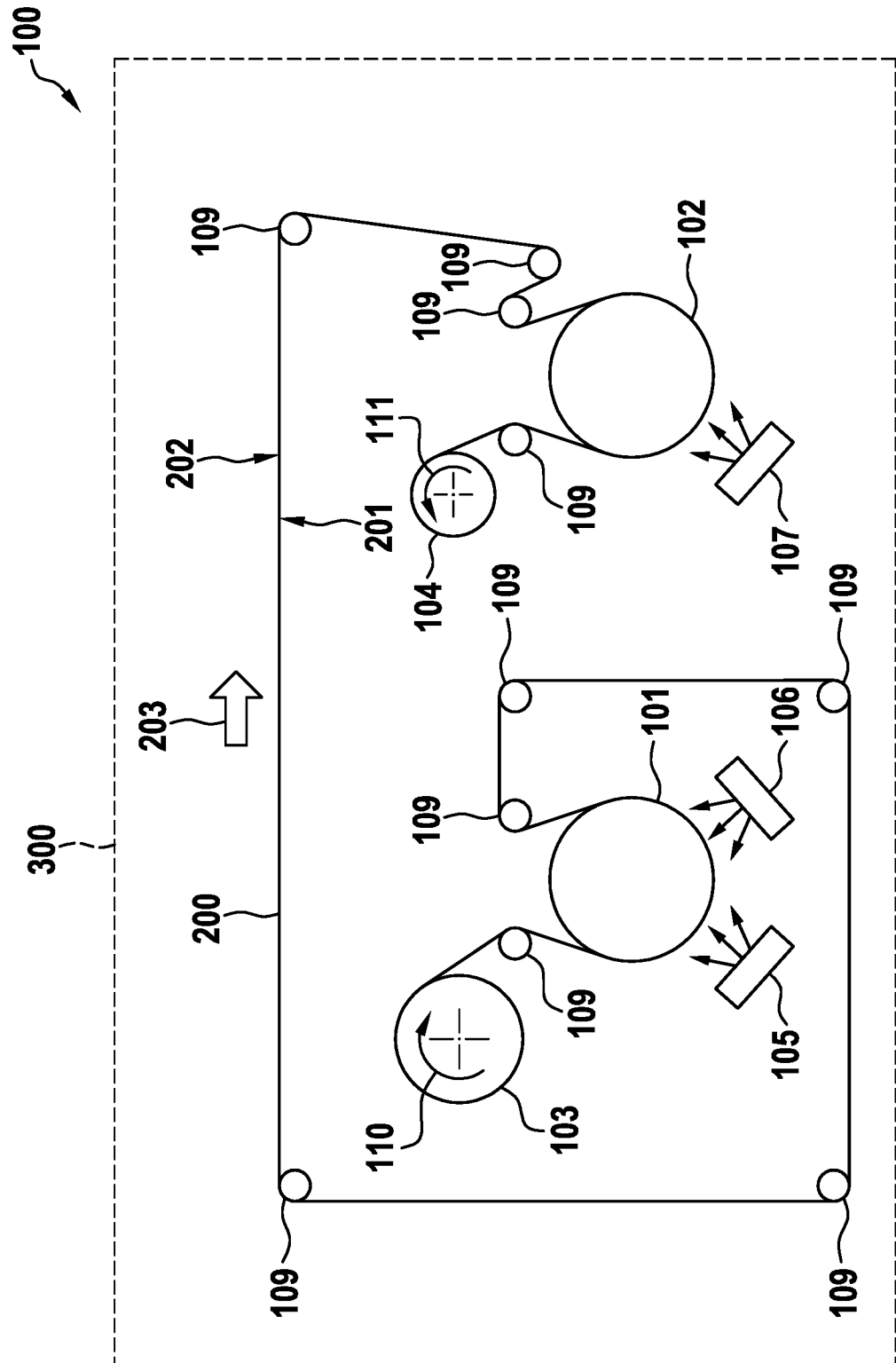


Fig. 3

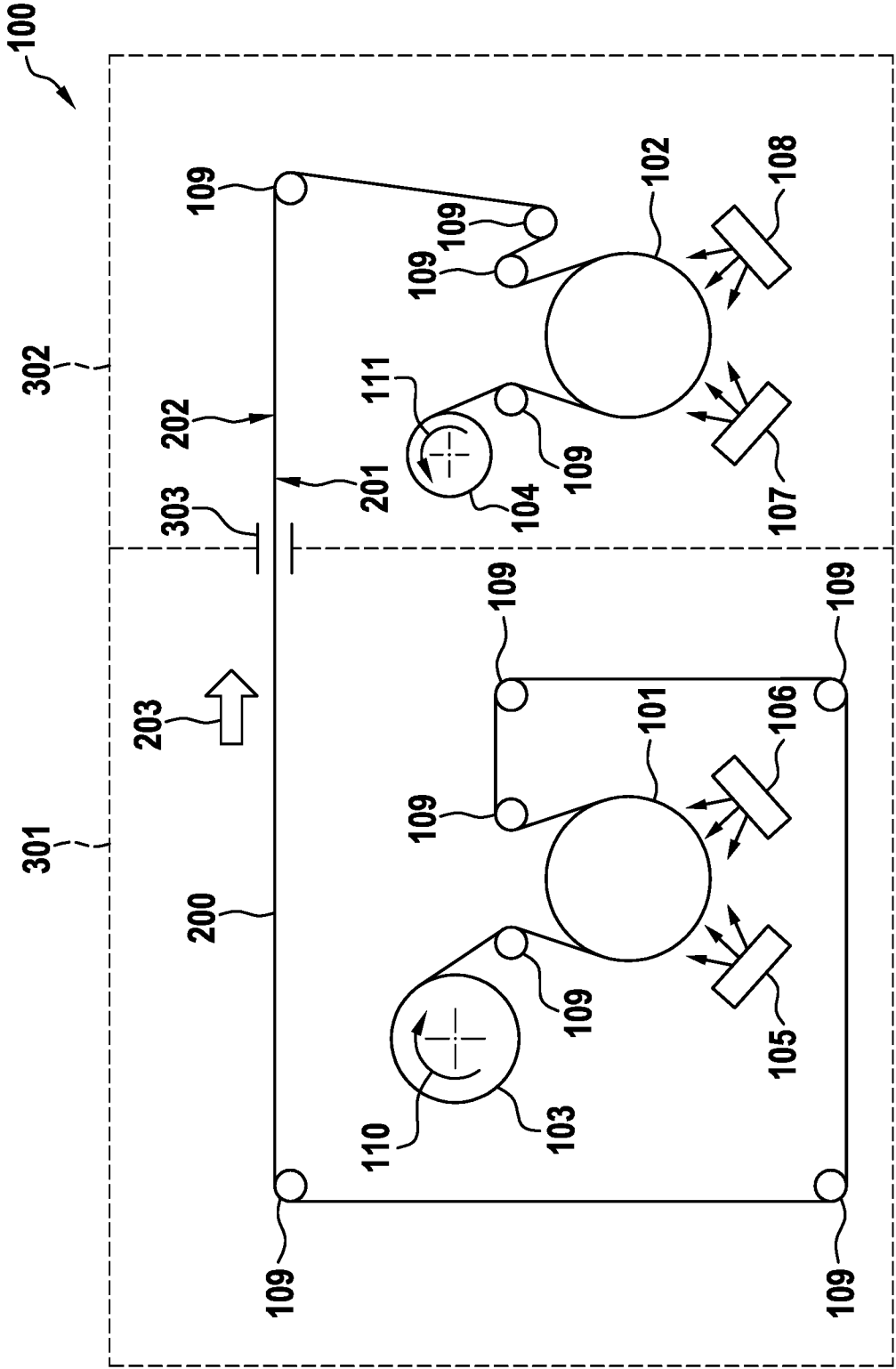
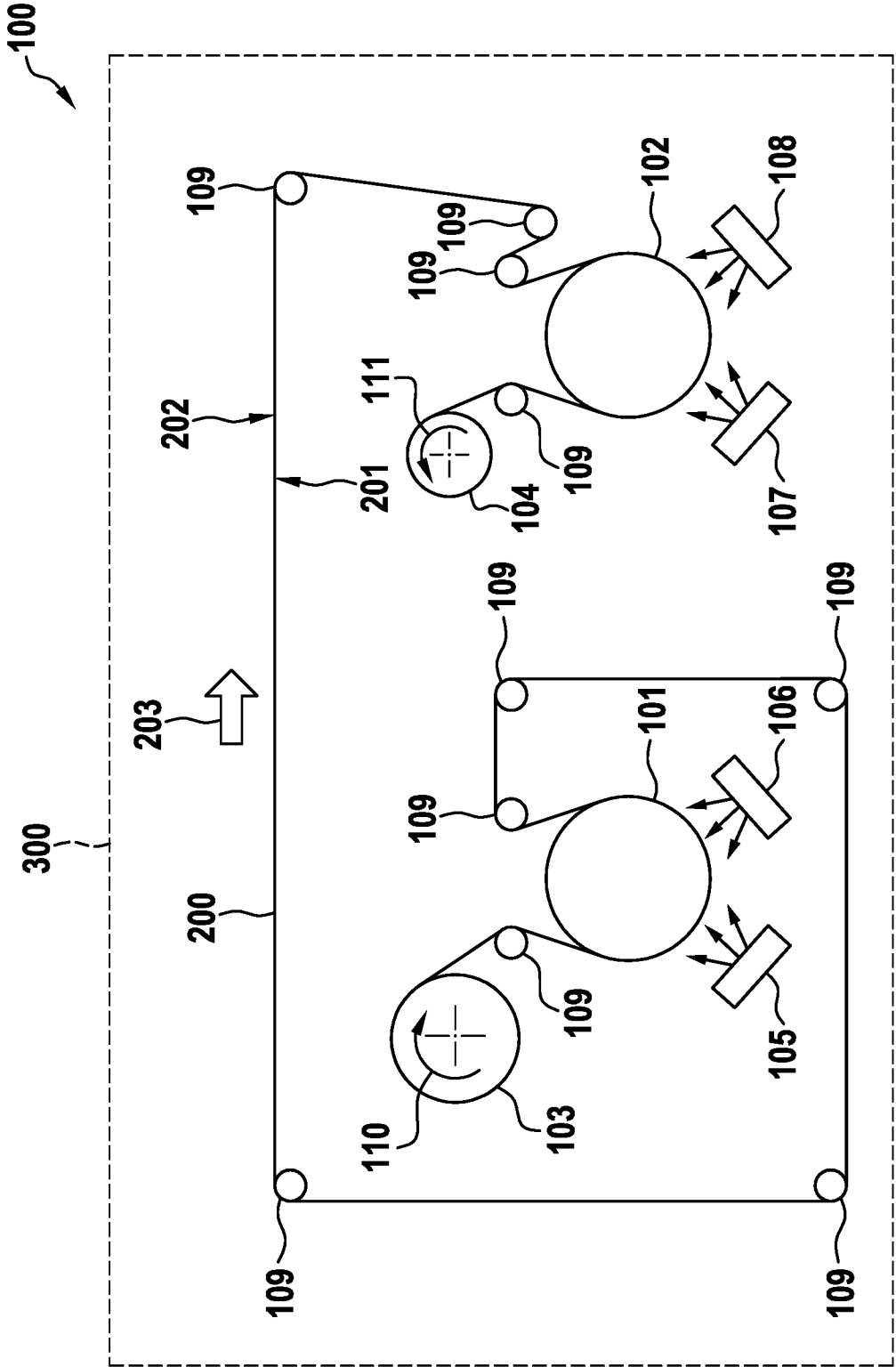


Fig. 4



5 / 5

Fig. 5

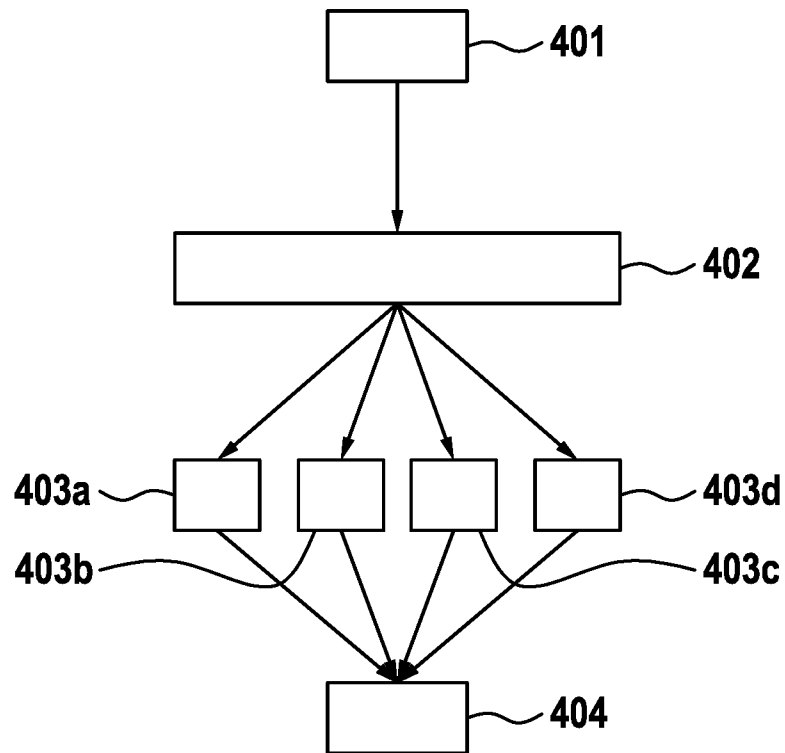
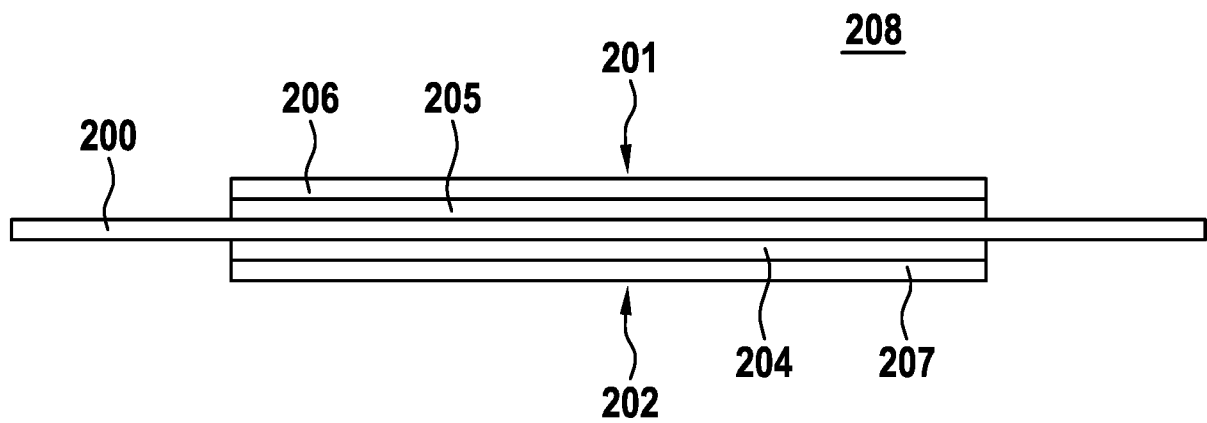


Fig. 6



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2016/061567

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M4/04 H01M4/38 H01M4/40
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/127847 A1 (APPLIED MATERIALS INC [US]; PIERALISI FABIO [DE]; MÜHLFELD UWE [DE]) 28 August 2014 (2014-08-28) paragraph [0002] - paragraph [0024]; figures 1,2	1,7
X	DE 10 2010 032770 A1 (LI TEC BATTERY GMBH [DE]) 2 February 2012 (2012-02-02) paragraph [0046] - paragraph [0081]; figure 4	14,15
X	EP 2 172 995 A1 (PANASONIC CORP [JP]) 7 April 2010 (2010-04-07)	10-15
A	paragraph [0033] - paragraph [0074]; figures 3, 4	1-9
	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

31 January 2017

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08/02/2017

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INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2016/061567

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Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Information on patent family members

International application No

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