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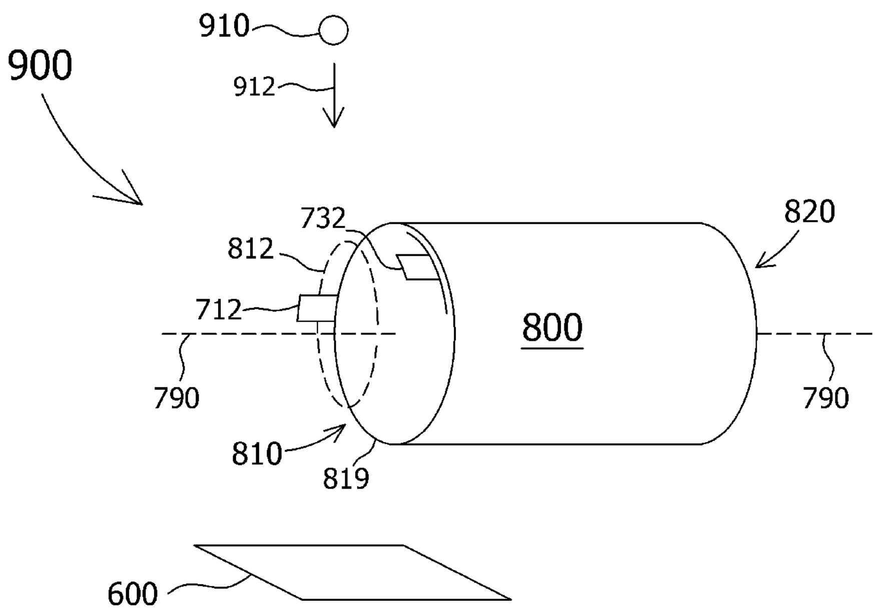

FIG. 9

(57) Abstract: A method, comprising capturing a first image (812i) of a first perimeter portion (812) of a first end (810) of a battery roll (800), wherein the first perimeter portion (812) comprises a first electrode (712), wherein the battery roll (800) comprises an anode layer (710), a cathode layer (730), and an electrolyte layer (720) which is sandwiched between and in direct physical contact with the anode layer (710) and the cathode layer (730), wherein the anode layer (710), the cathode layer (730), and the electrolyte layer (720) are rolled about an axis (790) resulting in the battery roll (800), and wherein the first electrode (712) is electrically connected to a first layer which is the anode layer (710) or the cathode layer (730); and identifying a first defect of the battery roll (800) related to the first electrode (712) based on the first image (812i).

WO 2023/283848 A1

[Continued on next page]

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BATTERY ROLL TESTING WITH IMAGING SYSTEMS

Background

[0001] A radiation detector is a device that measures a property of a radiation. Examples of the property may include a spatial distribution of the intensity, phase, and polarization of the radiation. The radiation measured by the radiation detector may be a radiation that has transmitted through an object. The radiation measured by the radiation detector may be an electromagnetic radiation such as infrared light, visible light, ultraviolet light, X-ray, or γ-ray. The radiation may be of other types such as α-rays and β-rays. An imaging system may include one or more image sensors each of which may have one or more radiation detectors.

Summary

[0002] Disclosed herein is a method, comprising: capturing a first image of a first perimeter portion of a first end of a battery roll, wherein the first perimeter portion comprises a first electrode, wherein the battery roll comprises an anode layer, a cathode layer, and an electrolyte layer which is sandwiched between and in direct physical contact with the anode layer and the cathode layer, wherein the anode layer, the cathode layer, and the electrolyte layer are rolled about an axis resulting in the battery roll, and wherein the first electrode is electrically connected to a first layer which is the anode layer or the cathode layer; and identifying a first defect of the battery roll related to the first electrode based on the first image.

[0003] In an aspect, said capturing the first image is performed with an image sensor.

[0004] In an aspect, the battery roll further comprises a separation layer such that a layer of the anode layer and the cathode layer is sandwiched between the electrolyte layer and the separation layer.

[0005] In an aspect, the battery roll has a cylindrical shape.

[0006] In an aspect, the first image is captured using radiation that has transmitted through the first electrode and the first perimeter portion.

[0007] In an aspect, the radiation comprises X-ray photons.

[0008] In an aspect, each photon of the X-ray photons has energy of at least 100 KeV.

[0009] In an aspect, the radiation is part of a cone beam.

[0010] In an aspect, the battery roll has a shape of a cylinder, and a radiation ray of the radiation being used for capturing the first image and intersecting the first electrode and an image sensor is perpendicular to a plane which contains the axis and intersects the first electrode.

[0011] In an aspect, the first end of the battery roll is not entirely in the first image.

[0012] In an aspect, the first defect comprises an electrical disconnection between the first electrode and the first layer.

[0013] In an aspect, the first defect comprises a short circuit between the first electrode and a second layer which is not the first layer and which is the anode layer or the cathode layer.

[0014] In an aspect, the method further comprises capturing a second image of a second perimeter portion of the first end of the battery roll, wherein the second perimeter portion comprises a second electrode, and wherein the second electrode is electrically connected to the anode layer or the cathode layer; and identifying a second defect of the battery roll related to the second electrode based on the second image.

[0015] In an aspect, the battery roll has a shape of a cylinder, wherein said capturing the second image comprises rotating the battery roll about the axis, and wherein a radiation ray of radiation being used for capturing the second image and intersecting the second electrode and an image sensor is perpendicular to a plane which contains the axis and intersects the second electrode.

[0016] In an aspect, the method further comprises capturing a third image of a third perimeter portion of a second end of the battery roll, wherein the third perimeter portion comprises a third electrode, wherein the third electrode is electrically connected to the anode layer or the cathode layer; and identifying a third defect of the battery roll related to the third electrode based on the third image.

[0017] In an aspect, the second end of the battery roll is not entirely in the third image.

[0018] In an aspect, the first perimeter portion comprises a fourth electrode, wherein the fourth electrode is electrically connected to the anode layer or the cathode layer, and wherein the fourth electrode is not electrically connected to the first layer.

[0019] In an aspect, the first defect comprises a short circuit between the first electrode and the fourth electrode.

[0020] In an aspect, the method further comprises capturing additional images, wherein the battery roll has a shape of a cylinder, wherein each point of a perimeter of the first end of the battery roll is in at least an image of the first and additional images, and wherein a radiation ray of radiation being used for capturing the image and intersecting the point and a same image sensor is essentially perpendicular to a plane which contains the axis and intersects the point.

[0021] In an aspect, the method further comprises rotating the battery roll about the axis, wherein the first and additional images are captured as the battery roll rotates about the axis.

[0022] In an aspect, the method further comprises capturing additional images such that each point of a perimeter of the first end of the battery roll is in at least an image of the first and additional images; and rotating the battery roll about the axis, wherein the first and additional images are captured as the battery roll rotates about the axis.

Brief Description of Figures

[0023] Fig. 1 schematically shows a radiation detector, according to an embodiment.

[0024] Fig. 2 schematically shows a simplified cross-sectional view of the radiation detector, according to an embodiment.

[0025] Fig. 3 schematically shows a detailed cross-sectional view of the radiation detector, according to an embodiment.

[0026] Fig. 4 schematically shows a detailed cross-sectional view of the radiation detector, according to an alternative embodiment.

[0027] Fig. 5 schematically shows a top view of a package including the radiation detector and a printed circuit board (PCB), according to an embodiment.

[0028] Fig. 6A schematically shows a cross-sectional view of an image sensor including the packages of Fig. 5 mounted to a system PCB (printed circuit board), according to an embodiment.

[0029] Fig. 6B schematically shows a top view of the image sensor, according to an alternative embodiment.

[0030] Fig. 7 schematically shows a perspective view of a battery layer stack, according to an embodiment.

[0031] Fig. 8 schematically shows a perspective view of a battery roll, according to an embodiment.

[0032] Fig. 9 schematically shows a perspective view of an imaging system, according to an embodiment.

[0033] Fig. 10A - Fig. 10B schematically show the imaging system in operation, according to an embodiment.

[0034] Fig. 11 shows a flowchart generalizing the operation of the imaging system.

[0035] Fig. 12A - Fig. 13B schematically show the imaging system in operation, according to different embodiments.

Detailed Description

[0036] RADIATION DETECTOR

[0037] Fig. 1 schematically shows a radiation detector 100, as an example. The radiation detector 100 may include an array of pixels 150 (also referred to as sensing elements 150). The array may be a rectangular array (as shown in Fig. 1), a honeycomb array, a hexagonal array, or any other suitable array. The array of pixels 150 in the example of Fig. 1 has 4 rows and 7 columns; however, in general, the array of pixels 150 may have any number of rows and any number of columns.

[0038] Each pixel 150 may be configured to detect radiation from a radiation source (not shown) incident thereon and may be configured to measure a characteristic (e.g., the energy of the particles, the wavelength, and the frequency) of the radiation. A radiation may include particles such as photons and subatomic particles. Each pixel 150 may be configured to count numbers of particles of radiation incident thereon whose energy falls in a plurality of bins of energy, within a period of time. All the pixels 150 may be configured to count the numbers of particles of radiation incident thereon within a plurality of bins of energy within the same period of time. When the incident particles of radiation have similar energy, the pixels 150 may be simply configured to count numbers of particles of radiation incident thereon within a period of time, without measuring the energy of the individual particles of radiation.

[0039] Each pixel 150 may have its own analog-to-digital converter (ADC) configured to digitize an analog signal representing the energy of an incident particle of radiation into a digital signal, or to digitize an analog signal representing the total energy of a plurality of incident particles of radiation into a digital signal. The pixels 150 may be configured to operate in parallel. For example, when one pixel 150 measures an incident particle of radiation, another pixel 150 may be waiting for a particle of radiation to arrive. The pixels 150 may not have to be individually addressable.

[0040] The radiation detector 100 described here may have applications such as in an X-ray telescope, X-ray mammography, industrial X-ray defect detection, X-ray microscopy or microradiography, X-ray casting inspection, X-ray non-destructive testing, X-ray weld inspection, X-ray digital subtraction angiography, etc. It may be suitable to use this radiation detector 100 in place of a photographic plate, a photographic film, a PSP plate, an X-ray image intensifier, a scintillator, or another semiconductor X-ray detector.

[0041] Fig. 2 schematically shows a simplified cross-sectional view of the radiation detector 100 of Fig. 1 along a line 2-2, according to an embodiment. Specifically, the radiation detector 100 may include a radiation absorption layer 110 and an electronics layer 120 (which may include one or more ASICs or application-specific integrated circuits) for processing or analyzing electrical signals which incident radiation generates in the radiation absorption layer 110. The radiation detector 100 may or may not include a scintillator (not shown). The radiation absorption layer 110 may include a semiconductor material such as silicon, germanium, GaAs, CdTe, CdZnTe, or a combination thereof. The semiconductor material may have a high mass attenuation coefficient for the radiation of interest.

[0042] Fig. 3 schematically shows a detailed cross-sectional view of the radiation detector 100 of Fig. 1 along the line 2-2, as an example. Specifically, the radiation absorption layer 110 may include one or more diodes (e.g., p-i-n or p-n) formed by a first doped region 111, one or more discrete regions 114 of a second doped region 113. The second doped region 113 may be separated from the first doped region 111 by an optional intrinsic region 112. The discrete regions 114 may be separated from one another by the first doped region 111 or the intrinsic region 112. The first doped region 111 and the second doped region 113 may have opposite types of doping (e.g., region 111 is p-type and region 113 is n-type, or region 111 is n-type and region 113 is p-type). In the example of Fig. 3, each of the discrete regions 114 of the second doped region 113 forms a diode with the first doped region 111 and the optional intrinsic region 112. Namely, in the example in Fig. 3, the radiation absorption layer 110 has a plurality of diodes (more specifically, 7 diodes corresponding to 7 pixels 150 of one row in the array of Fig. 1, of which only 2 pixels 150 are labeled in Fig. 3 for simplicity). The plurality of diodes may have an electrical contact 119A as a shared (common) electrode. The first doped region 111 may also have discrete portions.

[0043] The electronics layer 120 may include an electronic system 121 suitable for processing or interpreting signals generated by the radiation incident on the radiation absorption layer 110. The electronic system 121 may include an analog circuitry such as a filter network, amplifiers, integrators, and comparators, or a digital circuitry such as a microprocessor, and memory. The electronic system 121 may include one or more ADCs (analog to digital converters). The electronic system 121 may include components shared by the pixels 150 or components dedicated to a single pixel 150. For example, the electronic system 121 may include an amplifier dedicated to each pixel 150 and a microprocessor shared among all the pixels 150. The electronic system 121 may be electrically connected to the pixels 150 by vias 131. Space among the vias may be filled with a filler material 130, which may increase the mechanical stability of the connection of the electronics layer 120 to the radiation absorption layer 110. Other bonding techniques are possible to connect the electronic system 121 to the pixels 150 without using the vias 131.

[0044] When radiation from the radiation source (not shown) hits the radiation absorption layer 110 including diodes, particles of the radiation may be absorbed and generate one or more charge carriers (e.g., electrons, holes) by a number of mechanisms. The charge carriers may drift to the electrodes of one of the diodes under an electric field. The electric field may be an external electric field. The electrical contact 119B may include discrete portions each of which is in electrical contact with the discrete regions 114. The term “electrical contact” may be used interchangeably with the word “electrode.” In an embodiment, the charge carriers may drift in directions such that the charge carriers generated by a single particle of the radiation are not substantially shared by two different discrete regions 114 (“not substantially shared” here means less than 2%, less than 0.5%, less than 0.1%, or less than 0.01% of these charge carriers flow to a different one of the discrete regions 114 than the rest of the charge carriers). Charge carriers generated by a particle of the radiation incident around the footprint of one of these discrete regions 114 are not substantially shared with another of these discrete regions 114. A pixel 150 associated with a discrete region 114 may be an area around the discrete region 114 in which substantially all (more than 98%, more than 99.5%, more than 99.9%, or more than 99.99% of) charge carriers generated by a particle of the radiation incident therein flow to the discrete region 114. Namely, less than 2%, less than 1%, less than 0.1%, or less than 0.01% of these charge carriers flow beyond the pixel 150.

[0045] Fig. 4 schematically shows a detailed cross-sectional view of the radiation detector 100 of Fig. 1 along the line 2-2, according to an alternative embodiment. More specifically, the radiation absorption layer 110 may include a resistor of a semiconductor material such as silicon, germanium, GaAs, CdTe, CdZnTe, or a combination thereof, but does not include a diode. The semiconductor material may have a high mass attenuation coefficient for the radiation of interest. In an embodiment, the electronics layer 120 of Fig. 4 is similar to the electronics layer 120 of Fig. 3 in terms of structure and function.

[0046] When the radiation hits the radiation absorption layer 110 including the resistor but not diodes, it may be absorbed and generate one or more charge carriers by a number of mechanisms. A particle of the radiation may generate 10 to 100,000 charge carriers. The charge carriers may drift to the electrical contacts 119A and 119B under an electric field. The electric field may be an external electric field. The electrical contact 119B may include discrete portions. In an embodiment, the charge carriers may drift in directions such that the charge carriers generated by a single particle of the radiation are not substantially shared by two different discrete portions of the electrical contact 119B (“not substantially shared” here means less than 2%, less than 0.5%, less than 0.1%, or less than 0.01% of these charge carriers flow to a different one of the discrete portions than the rest of the charge carriers). Charge carriers generated by a particle of the radiation incident around the footprint of one of these discrete portions of the electrical contact 119B are not substantially shared with another of these discrete portions of the electrical contact 119B. A pixel 150 associated with a discrete portion of the electrical contact 119B may be an area around the discrete portion in which substantially all (more than 98%, more than 99.5%, more than 99.9% or more than 99.99% of) charge carriers generated by a particle of the radiation incident therein flow to the discrete portion of the electrical contact 119B. Namely, less than 2%, less than 0.5%, less than 0.1%, or less than 0.01% of these charge carriers flow beyond the pixel associated with the one discrete portion of the electrical contact 119B.

[0047] RADIATION DETECTOR PACKAGE

[0048] Fig. 5 schematically shows a top view of a package 500 including the radiation detector 100 and a printed circuit board (PCB) 510. The term “PCB” as used herein is not limited to a particular material. For example, a PCB may include a semiconductor. The radiation detector 100 may be mounted to the PCB 510. The wiring between the radiation detector 100 and the PCB 510 is not shown for the sake of clarity. The PCB 510 may have one or more radiation detectors 100. The PCB 510 may have an area 512 not covered by the radiation detector 100 (e.g., for accommodating bonding wires 514). The radiation detector 100 may have an active area 190 which is where the pixels 150 (Fig. 1) are located. The radiation detector 100 may have a perimeter zone 195 near the edges of the radiation detector 100. The perimeter zone 195 has no pixels 150, and the radiation detector 100 does not detect particles of radiation incident on the perimeter zone 195.

[0049] IMAGE SENSOR

[0050] Fig. 6A schematically shows a cross-sectional view of an image sensor 600, according to an embodiment. The image sensor 600 may include one or more packages 500 of Fig. 5 mounted to a system PCB 650. Fig. 6A shows 2 packages 500 as an example. The electrical connection between the PCBs 510 and the system PCB 650 may be made by bonding wires 514. In order to accommodate the bonding wires 514 on the PCB 510, the PCB 510 may have the area 512 not covered by the radiation detector 100. In order to accommodate the bonding wires 514 on the system PCB 650, the packages 500 may have gaps in between. The gaps may be approximately 1 mm or more. Particles of radiation incident on the perimeter zones 195, on the area 512, or on the gaps cannot be detected by the packages 500 on the system PCB 650. A dead zone of a radiation detector (e.g., the radiation detector 100) is the area of the radiation-receiving surface of the radiation detector, on which incident particles of radiation cannot be detected by the radiation detector. A dead zone of a package (e.g., package 500) is the area of the radiation-receiving surface of the package, on which incident particles of radiation cannot be detected by the radiation detector or detectors in the package. In this example shown in Fig. 5 and Fig. 6A, the dead zone of the package 500 includes the perimeter zones 195 and the area 512. A dead zone (e.g., 688) of an image sensor (e.g., image sensor 600) with a group of packages (e.g., packages 500 mounted on the same PCB and arranged in the same layer or in different layers) includes the combination of the dead zones of the packages in the group and the gaps between the packages.

[0051] In an embodiment, the radiation detector 100 (Fig. 1) operating by itself may be considered an image sensor. In an embodiment, the package 500 (Fig. 5) operating by itself may be considered an image sensor.

[0052] The image sensor 600 including the radiation detectors 100 may have the dead zone 688 among the active areas 190 of the radiation detectors 100. However, the image sensor 600 may capture multiple partial images of an object or scene (not shown), and then these captured partial images may be stitched to form an image of the entire object or scene.

[0053] The term “image” in the present specification is not limited to spatial distribution of a property of a radiation (such as intensity). For example, the term “image” may also include the spatial distribution of density of a substance or element.

[0054] Fig. 6B schematically shows a top view of the image sensor 600, according to an alternative embodiment. In this alternative embodiment, the image sensor 600 may include multiple radiation detectors 100 arranged in an overlapping manner such that there is no dead zone 688 (Fig. 6A) among the active areas 190 of the radiation detectors 100. For simplicity, only the active areas 190 of the radiation detectors 100 are shown in Fig. 6B.

[0055] BATTERY LAYER STACK

[0056] Fig. 7 schematically shows a perspective view of a battery layer stack 700, according to an embodiment. In an embodiment, the battery layer stack 700 may include an anode layer 710, an electrolyte layer 720, and a cathode layer 730, wherein the electrolyte layer 720 is sandwiched between and in direct physical contact with the anode layer 710 and cathode layer 730. In an embodiment, the anode layer 710, the electrolyte layer 720, and the cathode layer 730 may form a lithium-ion battery.

[0057] In an embodiment, the battery layer stack 700 may further include (A) a first electrode 712 electrically connected to the anode layer 710, and (B) a second electrode 732 electrically connected to the cathode layer 730.

[0058] In an embodiment, the battery layer stack 700 may further include a separation layer 740 such that the cathode layer 730 is sandwiched between the electrolyte layer 720 and the separation layer 740. In an embodiment, the separation layer 740 may include an insulator.

[0059] In an embodiment, the battery layer stack 700 may be rolled about an axis 790 resulting in a battery roll 800 (Fig. 8). With reference to Fig. 8, the battery roll 800 may have a cylindrical shape as shown. In an embodiment, the battery roll 800 may have a first end 810 and a second end 820 as shown.

[0060] IMAGING SYSTEM SETUP

[0061] Fig. 9 schematically shows a perspective view of an imaging system 900, according to an embodiment. In an embodiment, the imaging system 900 may include a radiation source 910 and the image sensor 600.

[0062] In an embodiment, the battery roll 800 may be arranged such that a perimeter portion 812 of the first end 810 of the battery roll 800 is between the radiation source 910 and the image sensor 600. In an embodiment, the perimeter portion 812 may contain a section of the perimeter 819 of the first end 810 of the battery roll 800. In an embodiment, the first electrode 712 may be part of the perimeter portion 812.

[0063] In an embodiment, the radiation source 910 may generate a radiation beam 912 toward the perimeter portion 812 and then toward the image sensor 600. The radiation beam 912 may be used for imaging the perimeter portion 812 (including the first electrode 712). In an embodiment, the radiation beam 912 may be X-rays with high energy (e.g., each X-ray photon of the radiation beam 912 may have energy of at least 100 KeV). In an embodiment, the radiation beam 912 may be a cone beam.

[0064] In an embodiment, during the imaging of the perimeter portion 812, at least a radiation ray (not shown) of the radiation beam 912 that intersects the first electrode 712 and the image sensor 600 is perpendicular to a plane which (a) contains the axis 790 and (b) intersects the first electrode 712.

[0065] IMAGING OF FIRST PERIMETER PORTION 812

[0066] Fig. 10A shows a side view of the battery roll 800. In an embodiment, an image 812i (Fig. 10B) of the perimeter portion 812 (including the first electrode 712) may be captured using the radiation of the radiation beam 912 that has transmitted through the perimeter portion 812 (including the first electrode 712). In an embodiment, the image sensor 600 may capture the image 812i (Fig. 10B).

[0067] In an embodiment, the first end 810 of the battery roll 800 is not entirely in the image 812i. In other words, some portion of the first end 810 is not captured in the image 812i.

[0068] FIRST DEFECT IDENTIFICATION

[0069] In an embodiment, a first defect of the battery roll 800 related to the first electrode 712 may be identified based on the image 812i (Fig. 10B) of the perimeter portion 812.

[0070] For example, with reference to Fig. 7 and Fig. 10A - Fig. 10B the first defect of the battery roll 800 related to the first electrode 712 may include an electrical disconnection between the first electrode 712 and the anode layer 710. For another example, the first defect of the battery roll 800 related to the first electrode 712 may include a short circuit between the first electrode 712 and the cathode layer 730. For yet another example, the first defect of the battery roll 800 related to the first electrode 712 may include both (A) an electrical disconnection between the first electrode 712 and the anode layer 710, and (B) a short circuit between the first electrode 712 and the cathode layer 730.

[0071] FLOWCHART FOR GENERALIZATION

[0072] Fig. 11 shows a flowchart 1100 generalizing the operation of the imaging system 900 (Fig. 9 - Fig. 10B) described above. In step 1110, a first image of a first perimeter portion of a first end of a battery roll is captured. For example, in the embodiments described above, the image 812i of the perimeter portion 812 of the first end 810 of the battery roll 800 is captured.

[0073] In addition, also in step 1110, the first perimeter portion comprises a first electrode. For example, in the embodiments described above, the perimeter portion 812 includes the first electrode 712.

[0074] In addition, also in step 1110, the battery roll comprises an anode layer, a cathode layer, and an electrolyte layer which is sandwiched between and in direct physical contact with the anode layer and the cathode layer. For example, in the embodiments described above, the battery roll 800 includes the anode layer 710, the cathode layer 730, and the electrolyte layer 720 which is sandwiched between and in direct physical contact with the anode layer 710 and the cathode layer 730.

[0075] In addition, also in step 1110, the anode layer, the cathode layer, and the electrolyte layer are rolled about an axis resulting in the battery roll. For example, in the embodiments described above, the anode layer 710, the cathode layer 730, and the electrolyte layer 720 are rolled about the axis 790 resulting in the battery roll 800.

[0076] In addition, also in step 1110, the first electrode is electrically connected to a first layer which is the anode layer or the cathode layer. For example, in the embodiments described above, the first electrode 712 is electrically connected to the anode layer 710.

[0077] In step 1120, a first defect of the battery roll related to the first electrode is identified based on the first image. For example, in the embodiments described above, the first defect of the battery roll 800 related to the first electrode 712 is identified based on the image 812i.

[0078] IMAGING OF SECOND PERIMETER PORTION 832

[0079] In an embodiment, with reference to Fig. 10A, after the image sensor 600 captures the image 812i (Fig. 10B) of the perimeter portion 812 (including the first electrode 712), the battery roll 800 may be rotated about the axis 790 counterclockwise until a perimeter portion 832 which includes the second electrode 732 is positioned between the radiation source 910 and the image sensor 600 as shown in Fig. 12A. The perimeter portion 832 may contain a section of the perimeter 819 of the first end 810 of the battery roll 800.

[0080] Then, in an embodiment, with reference to Fig. 12A, an image 832i (Fig. 12B) of the perimeter portion 832 (including the second electrode 732) may be captured using the radiation of the radiation beam 912 that has transmitted through the perimeter portion 832 (including the second electrode 732). In an embodiment, the image sensor 600 may capture the image 832i (Fig. 12B).

[0081] In an embodiment, during the capturing of the image 832i of the perimeter portion 832, at least a radiation ray (not shown) of the radiation beam 912 that intersects the second electrode 732 and the image sensor 600 is perpendicular to a plane which (a) contains the axis 790 and (b) intersects the second electrode 732.

[0082] In an embodiment, the first end 810 of the battery roll 800 is not entirely in the image 832i (Fig. 12B). In other words, some portion of the first end 810 is not captured in the image 832i.

[0083] SECOND DEFECT IDENTIFICATION

[0084] In an embodiment, a second defect of the battery roll 800 related to the second electrode 732 may be identified based on the image 832i (Fig. 12B) of the perimeter portion 832.

[0085] For example, with reference to Fig. 7 and Fig. 12A - Fig. 12B, the second defect of the battery roll 800 related to the second electrode 732 may include an electrical disconnection between the second electrode 732 and the cathode layer 730. For another example, the second defect of the battery roll 800 related to the second electrode 732 may include a short circuit between the second electrode 732 and the anode layer 710. For yet another example, the second defect of the battery roll 800 related to the second electrode 732 may include both (A) an electrical disconnection between the second electrode 732 and the cathode layer 730, and (B) a short circuit between the second electrode 732 and the anode layer 710.

[0086] ALTERNATIVE EMBODIMENTS

[0087] FIRST AND SECOND ELECTRODES ARE IN PROXIMITY

[0088] In the embodiments described above, with reference to Fig. 10A, the first electrode 712 and the second electrode 732 are far away from each other, and therefore, 2 different images 812i and 832i are needed for identifying defects related to the electrodes 712 and 732 respectively. In an alternative embodiment, with reference to Fig. 13A, the first electrode 712 and the second electrode 732 may be close to each other such that the perimeter portion 812 includes both the electrodes 712 and 732. The image 812i of the perimeter portion 812 of Fig. 13A is shown in Fig. 13B.

[0089] As a result, both the first defect of the battery roll 800 related to the electrode 712 and the second defect of the battery roll 800 related to the electrode 732 may be identified based on the image 812i of Fig. 13B. In this alternative embodiment, besides the electrical disconnections and the short circuits mentioned above, the first defect of the battery roll 800 related to the first electrode 712 and the second defect of the battery roll 800 related to the second electrode 732 may also include a short circuit between the electrodes 712 and 732.

[0090] TWO ELECTRODES ARE ON TWO ENDS OF BATTERY ROLL

[0091] In the embodiments described above, with reference to Fig. 9, both the electrodes 712 and 732 are on the same end (i.e., the first end 810) of the battery roll 800. In an alternative embodiment, the electrodes 712 and 732 may be on different ends of the battery roll 800. For example, the first electrode 712 may be on the first end 810 of the battery roll 800, whereas the second electrode 732 may be on the second end 820 of the battery roll 800.

[0092] In that case, after the image 812i (Fig. 10B) is captured as described above, the battery roll 800 may be rotated 90 degrees about a vertical axis (not shown) and then rotated about the axis 790 so that the second electrode 732 and its corresponding perimeter portion 832 is between the radiation source 910 and the image sensor 600 for imaging. In an embodiment, the imaging of the second electrode 732 and its corresponding perimeter portion 832 may be similar to the imaging of the first electrode 712 and its corresponding perimeter portion 812 described above.

[0093] MULTIPLE ELECTRODES FOR EACH OF ANODE LAYER AND CATHODE LAYER

[0094] In the embodiments described above, with reference to Fig. 7 and Fig. 10A, each of the anode layer 710 and the cathode layer 730 has a single electrode. For instance, the anode layer 710 has a single electrode (i.e., the first electrode 712), and the cathode layer 730 has a single electrode (i.e., the second electrode 732). In an alternative embodiment, each of the anode layer 710 and the cathode layer 730 may have multiple electrodes. In that case, the imaging of each electrode and its corresponding perimeter portion may be similar to the imaging of the first electrode 712 and its corresponding perimeter portion 812 described above.

[0095] SCANNING ENTIRE PERIMETER

[0096] In the embodiments described above, with reference to Fig. 10A, the perimeter portions 812 and 832 are in turn scanned. Alternatively, the entire perimeter 819 may be scanned. Specifically, in an embodiment, the battery roll 800 may be rotated about the axis 790 as the image sensor 600 captures multiple images of perimeter portions of the first end 810 of the battery roll 800. In an embodiment, each of the perimeter portions contains a section of the perimeter 819.

[0097] In an embodiment, each point of the perimeter 819 is in at least an image of the multiple images captured by the image sensor 600. In addition, in an embodiment, for each point of the perimeter 819, a radiation ray of the radiation beam 912 being used for capturing an image of the point and intersecting the point and the image sensor 600 is essentially perpendicular to a plane which (a) contains the axis 790 and (b) intersects the point. Here, "essentially perpendicular" means perpendicular or almost perpendicular.

[0098] ANODE LAYER AND CATHODE LAYER SWITCH POSITIONS

[0099] In the embodiments described above, with reference to Fig. 7, from bottom to top are the anode layer 710, the electrolyte layer 720, the cathode layer 730, and the separation layer 740. In an alternative embodiment, the anode layer 710 and the cathode layer 730 may switch their respective positions in the battery layer stack 700. In other words, in Fig. 7, from bottom to top would be the cathode layer 730, the electrolyte layer 720, the anode layer 710, and the separation layer 740.

[00100] While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A method, comprising:

capturing a first image of a first perimeter portion of a first end of a battery roll,

wherein the first perimeter portion comprises a first electrode,

wherein the battery roll comprises an anode layer, a cathode layer, and an electrolyte layer which is sandwiched between and in direct physical contact with the anode layer and the cathode layer,

wherein the anode layer, the cathode layer, and the electrolyte layer are rolled about an axis resulting in the battery roll, and

wherein the first electrode is electrically connected to a first layer which is the anode layer or the cathode layer; and

identifying a first defect of the battery roll related to the first electrode based on the first image.

2. The method of claim 1, wherein said capturing the first image is performed with an image sensor.

3. The method of claim 1, wherein the battery roll further comprises a separation layer such that a layer of the anode layer and the cathode layer is sandwiched between the electrolyte layer and the separation layer.

4. The method of claim 1, wherein the battery roll has a cylindrical shape.

5. The method of claim 1, wherein the first image is captured using radiation that has transmitted through the first electrode and the first perimeter portion.

6. The method of claim 5, wherein the radiation comprises X-ray photons.

7. The method of claim 6, wherein each photon of the X-ray photons has energy of at least 100 KeV.

8. The method of claim 5, wherein the radiation is part of a cone beam.

9. The method of claim 5,

wherein the battery roll has a shape of a cylinder, and

wherein a radiation ray of the radiation being used for capturing the first image and intersecting the first electrode and an image sensor is perpendicular to a plane which contains the axis and intersects the first electrode.

10. The method of claim 9, wherein the first end of the battery roll is not entirely in the first image.

11. The method of claim 1, wherein the first defect comprises an electrical disconnection between the first electrode and the first layer.

12. The method of claim 1, wherein the first defect comprises a short circuit between the first electrode and a second layer which is not the first layer and which is the anode layer or the cathode layer.

13. The method of claim 1, further comprising:

capturing a second image of a second perimeter portion of the first end of the battery roll,

wherein the second perimeter portion comprises a second electrode, and

wherein the second electrode is electrically connected to the anode layer or the cathode layer; and

identifying a second defect of the battery roll related to the second electrode based on the second image.

14. The method of claim 13,

wherein the battery roll has a shape of a cylinder,

wherein said capturing the second image comprises rotating the battery roll about the axis, and

wherein a radiation ray of radiation being used for capturing the second image and intersecting the second electrode and an image sensor is perpendicular to a plane which contains the axis and intersects the second electrode.

15. The method of claim 1, further comprising:

capturing a third image of a third perimeter portion of a second end of the battery roll,

wherein the third perimeter portion comprises a third electrode,

wherein the third electrode is electrically connected to the anode layer or the cathode layer; and

identifying a third defect of the battery roll related to the third electrode based on the third image.

16. The method of claim 15, wherein the second end of the battery roll is not entirely in the third image.

17. The method of claim 1,

wherein the first perimeter portion comprises a fourth electrode, wherein the fourth electrode is electrically connected to the anode layer or the cathode layer, and

wherein the fourth electrode is not electrically connected to the first layer.

18. The method of claim 17, wherein the first defect comprises a short circuit between the first electrode and the fourth electrode.

19. The method of claim 1, further comprising capturing additional images,

wherein the battery roll has a shape of a cylinder,

wherein each point of a perimeter of the first end of the battery roll is in at least an image of the first and additional images, and

wherein a radiation ray of radiation being used for capturing the image and intersecting the point and a same image sensor is essentially perpendicular to a plane which contains the axis and intersects the point.

20. The method of claim 19, further comprising rotating the battery roll about the axis, wherein the first and additional images are captured as the battery roll rotates about the axis.

21. The method of claim 1, further comprising:

capturing additional images such that each point of a perimeter of the first end of the battery roll is in at least an image of the first and additional images; and

rotating the battery roll about the axis, wherein the first and additional images are captured as the battery roll rotates about the axis.

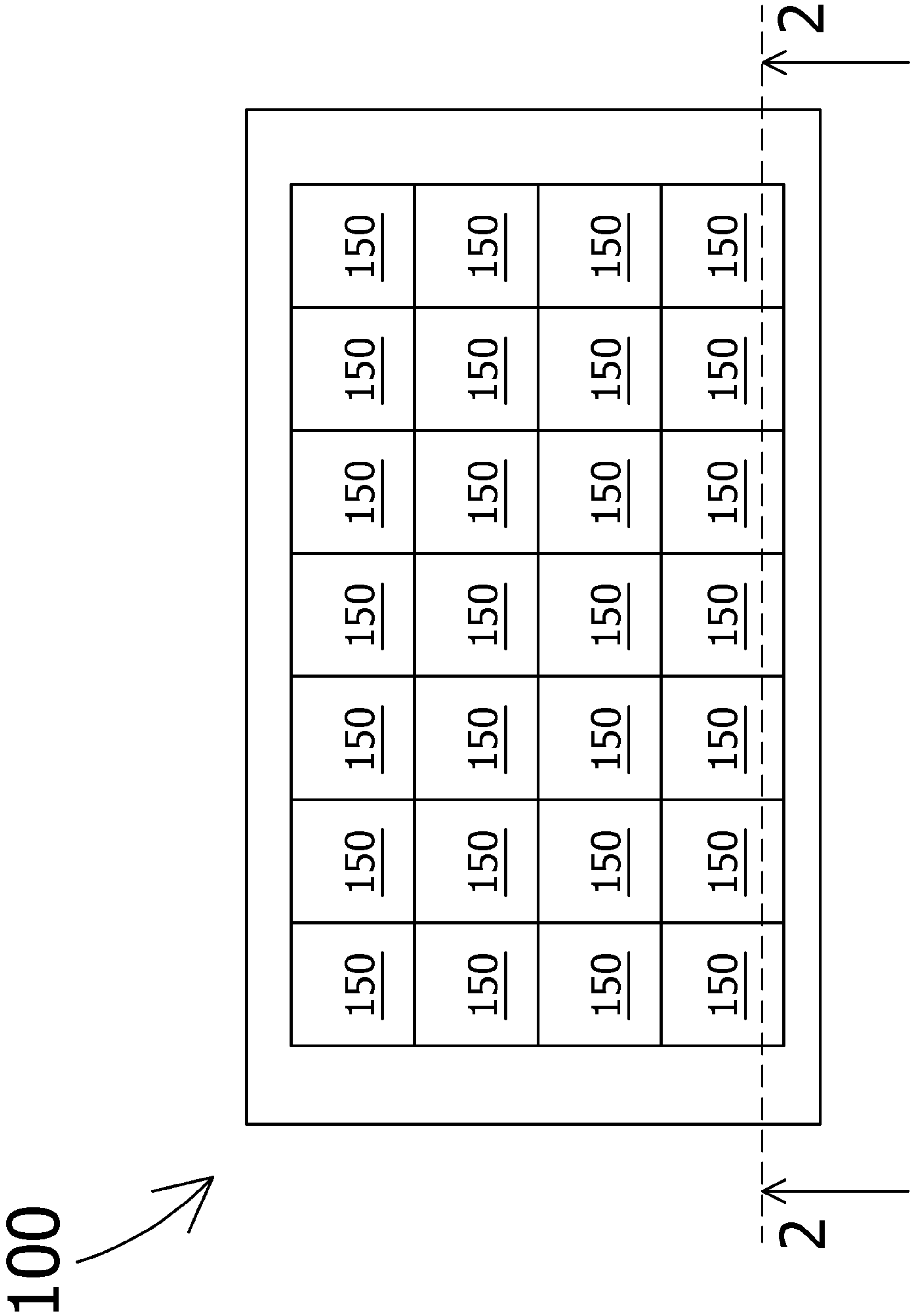

FIG. 1

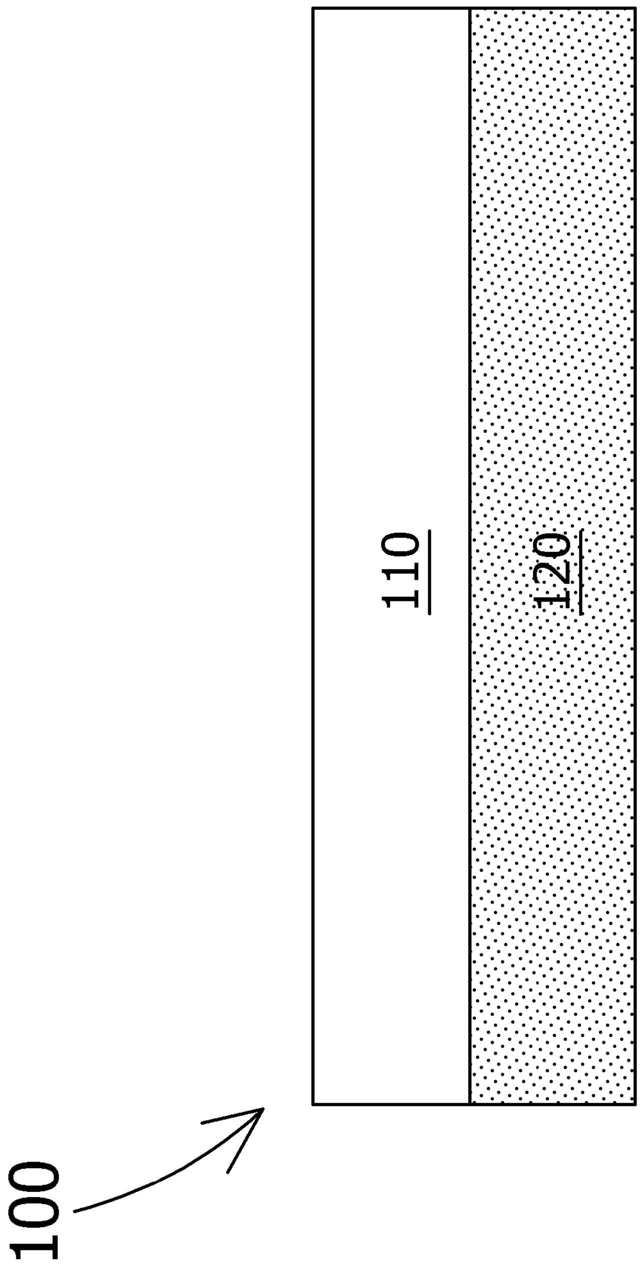

FIG. 2

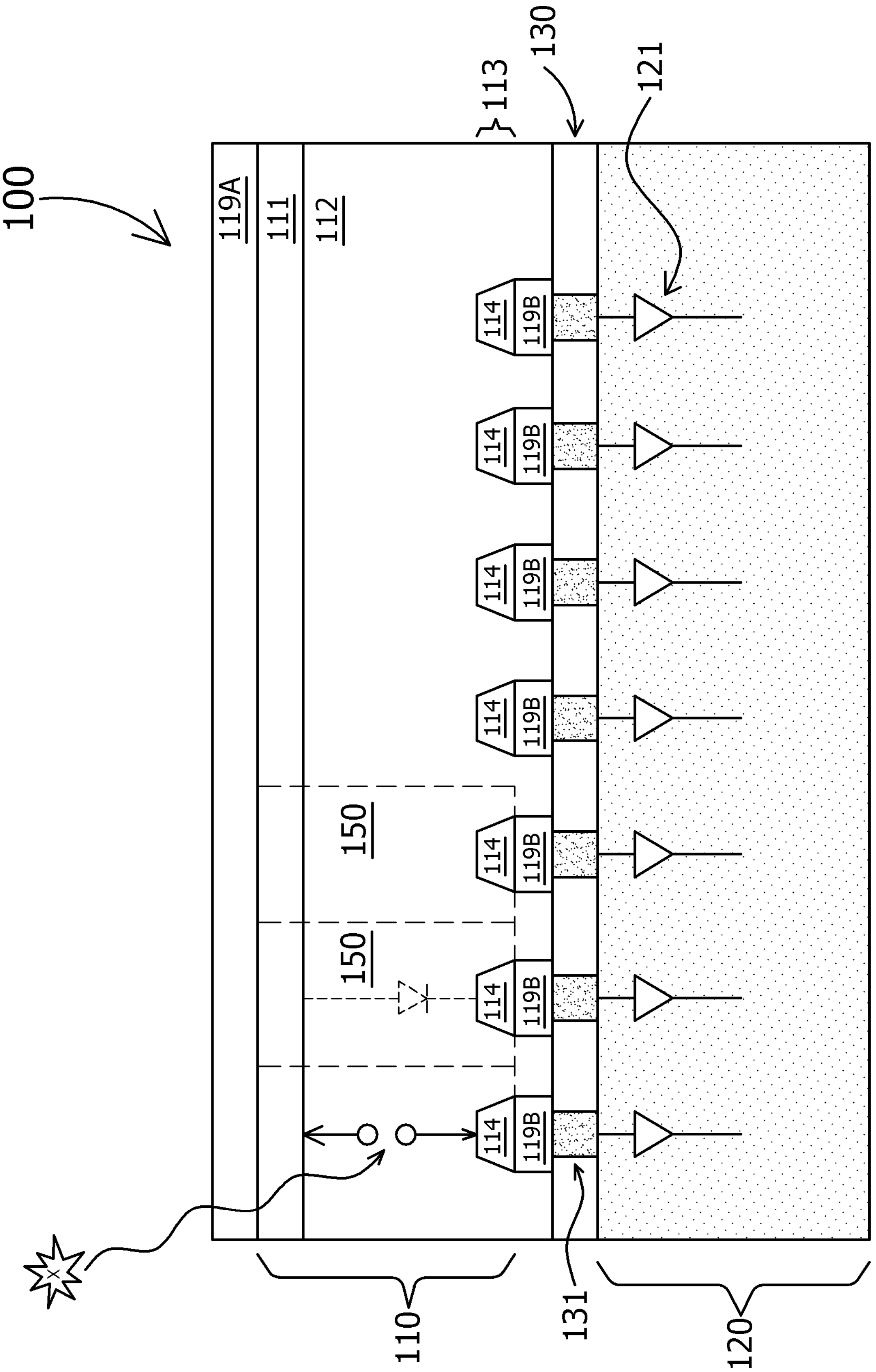

FIG. 3

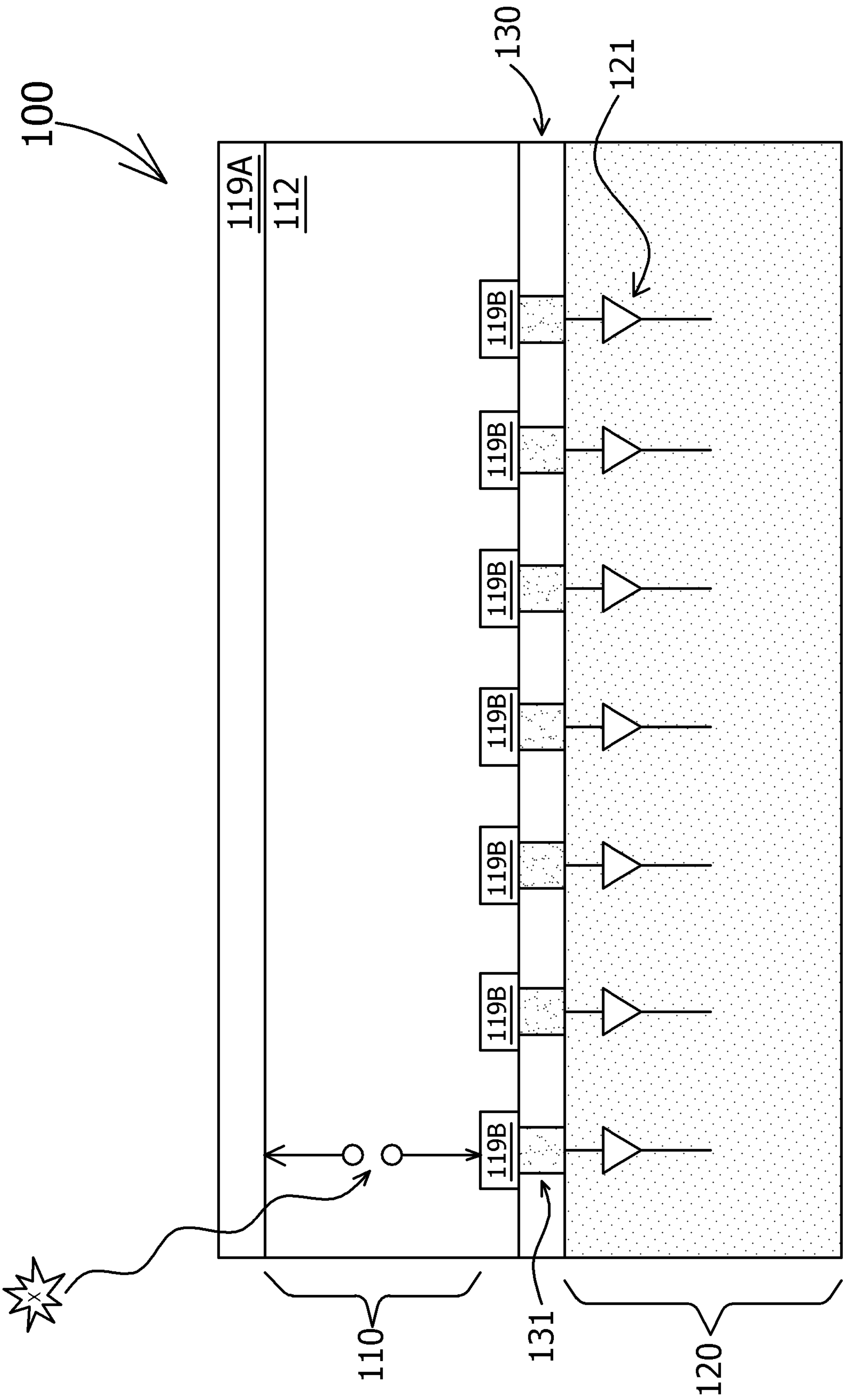
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FIG. 4

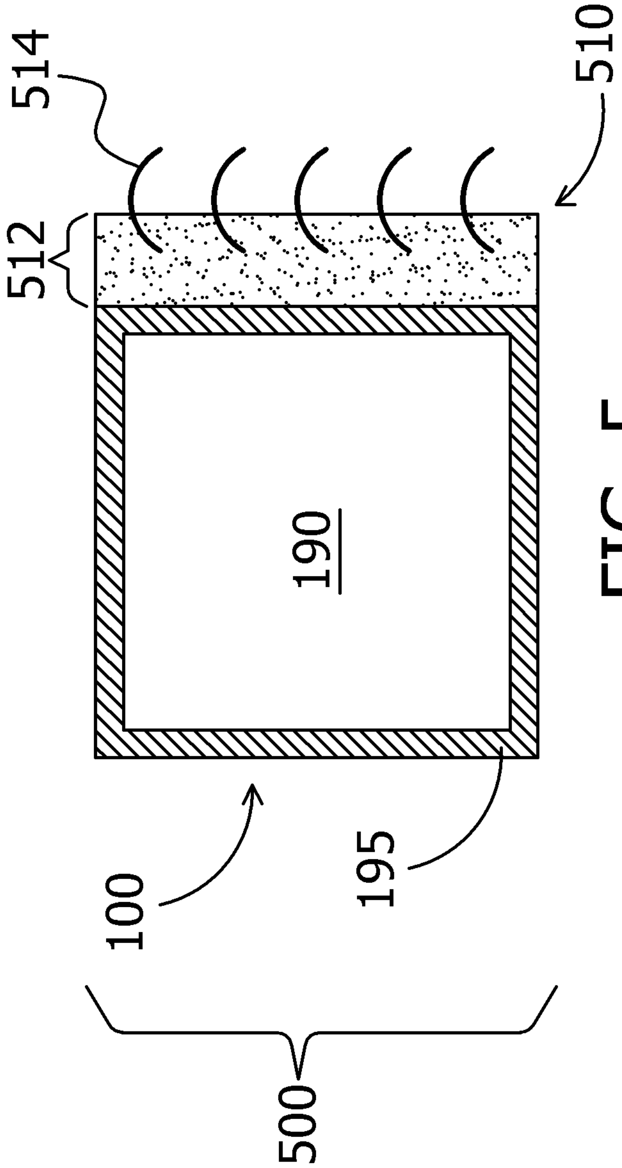
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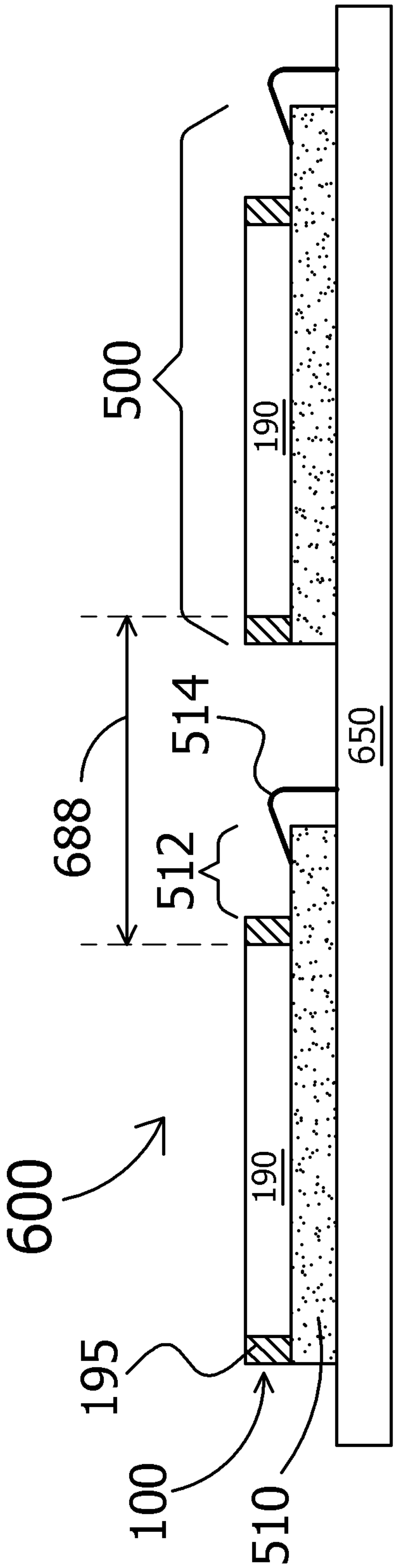
FIG. 5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100
510

FIG. 6A

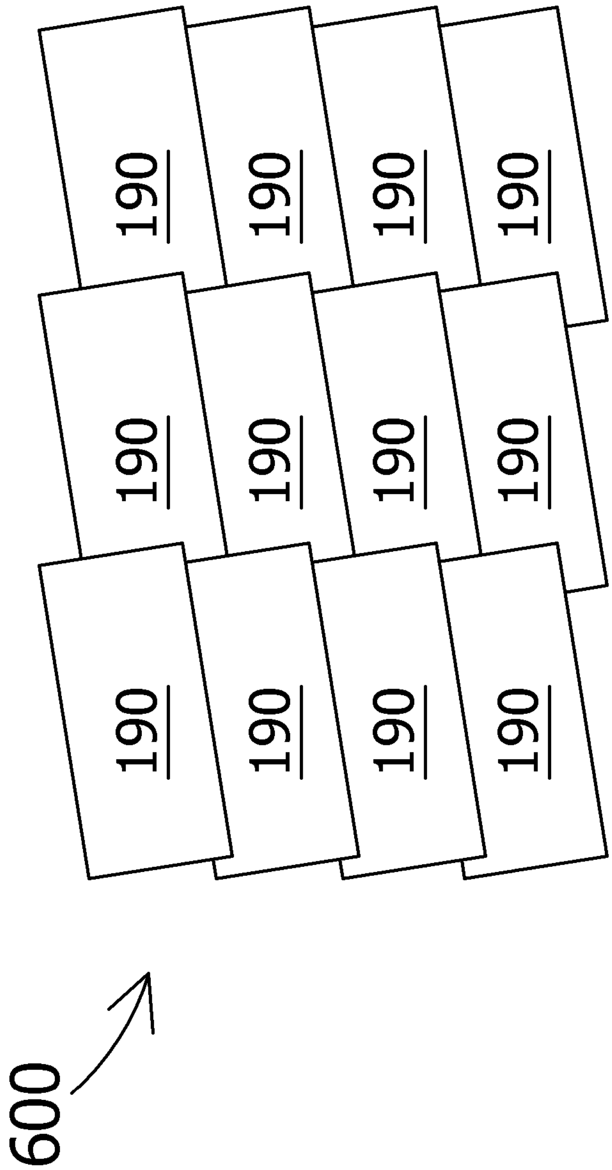

FIG. 6B

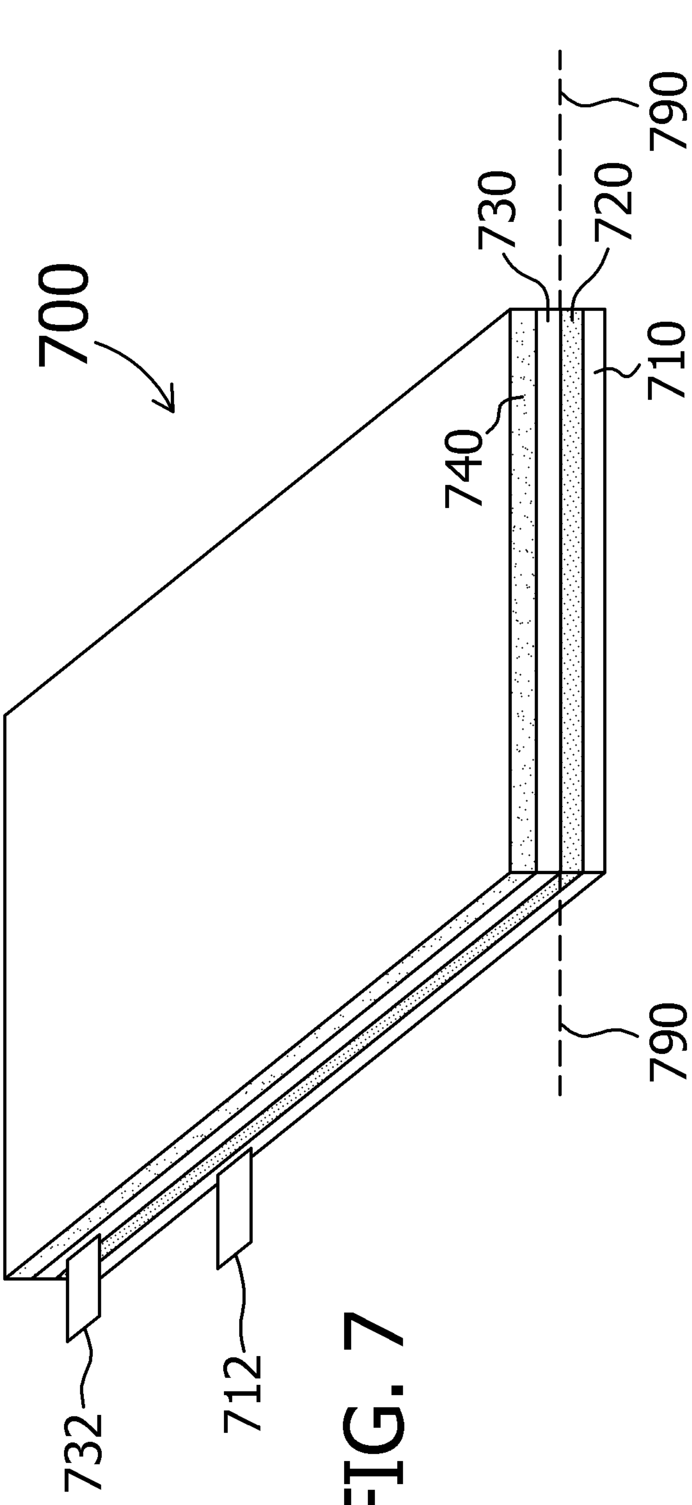

FIG. 7

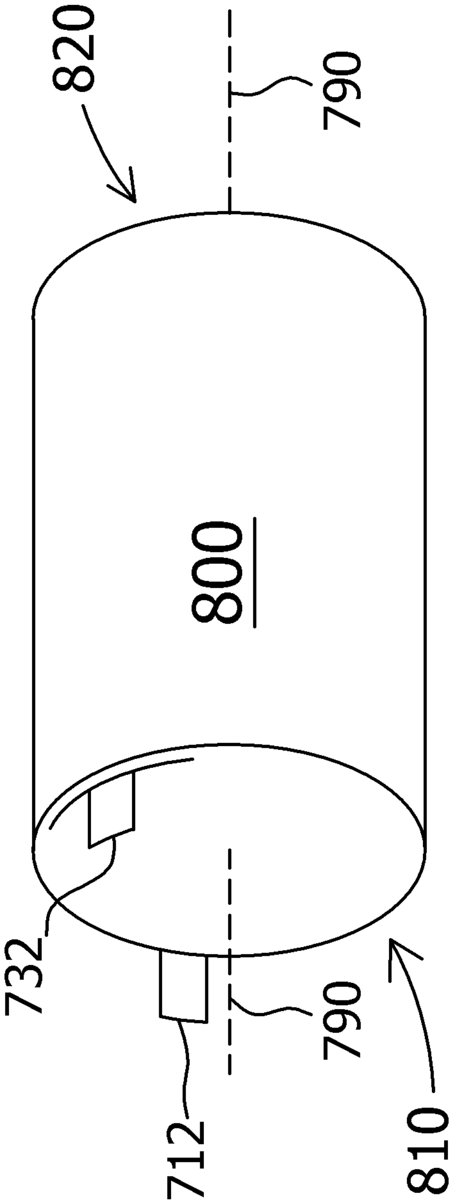

FIG. 8

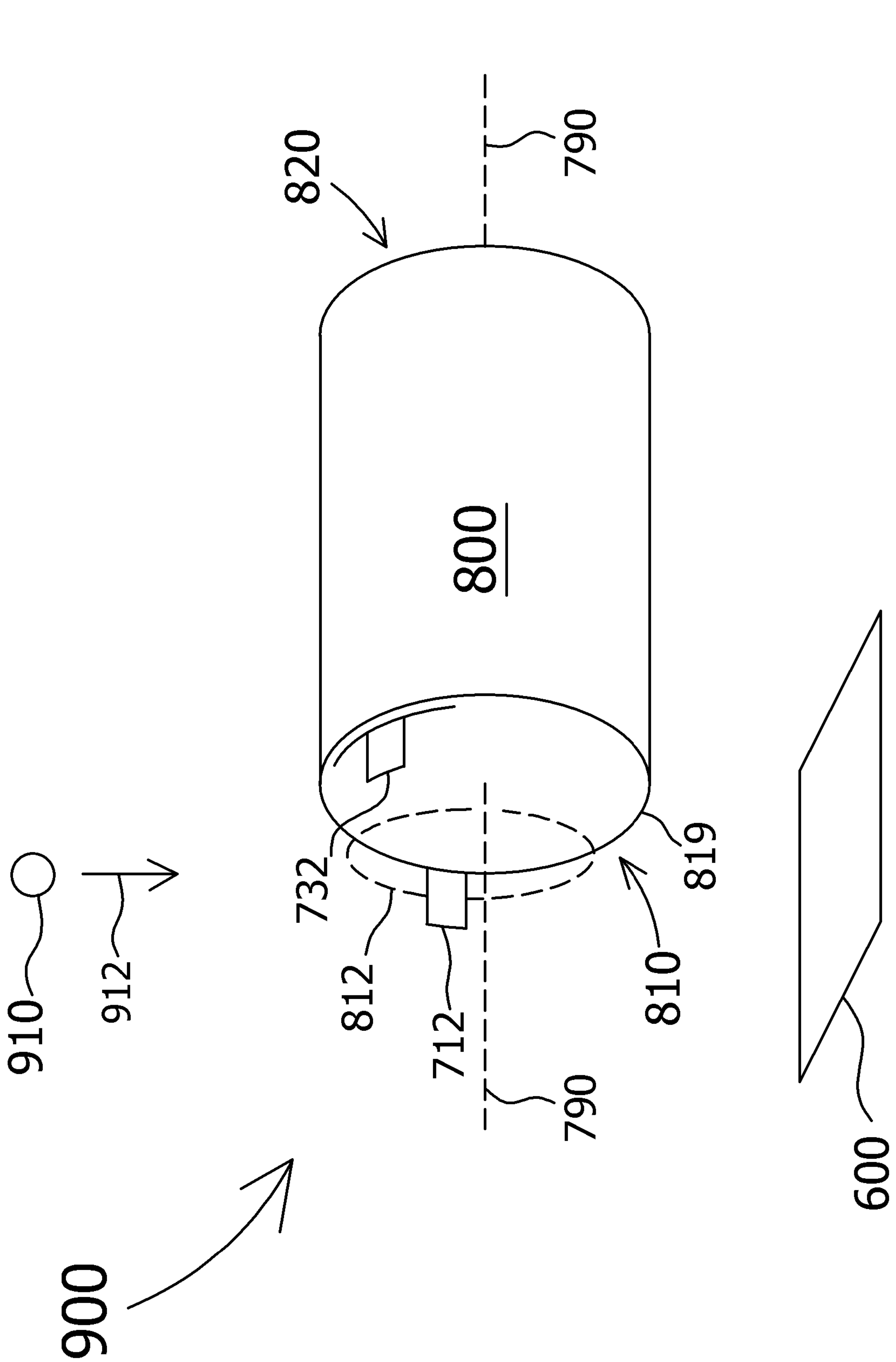

FIG. 9

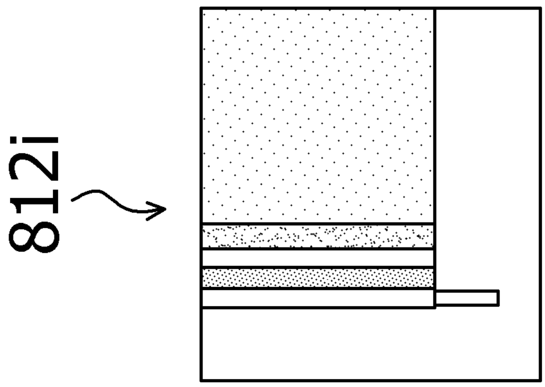

FIG. 10B

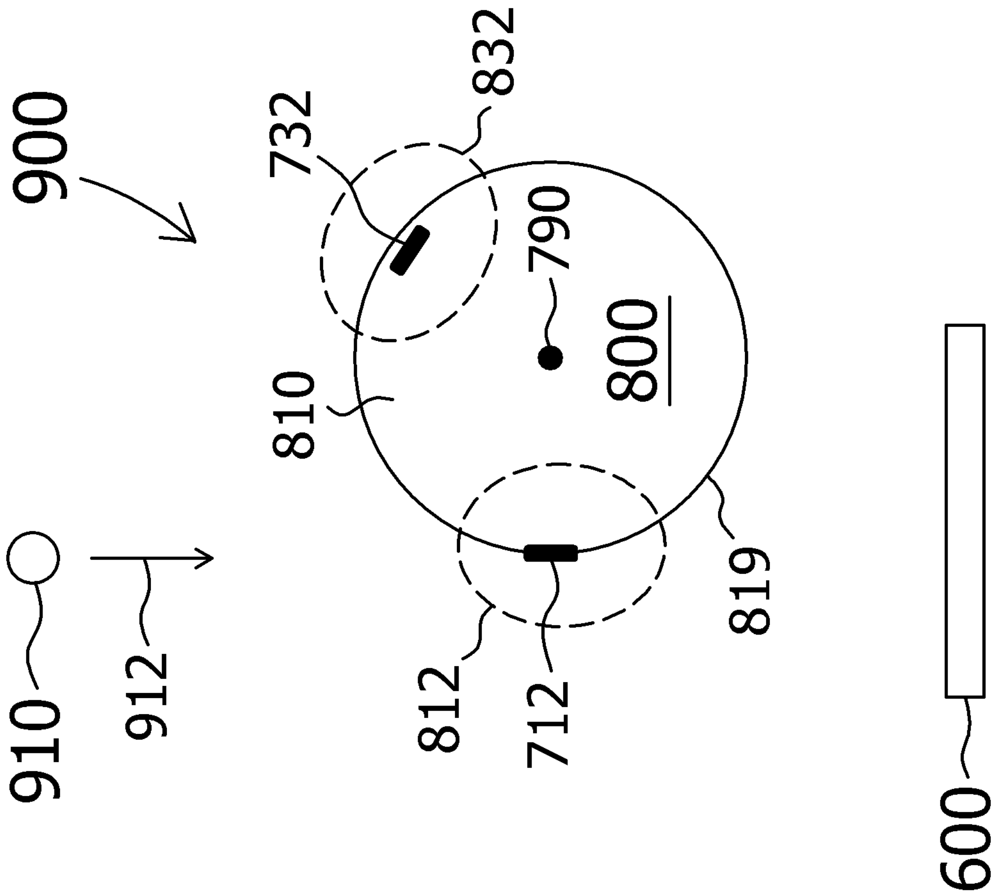

FIG. 10A

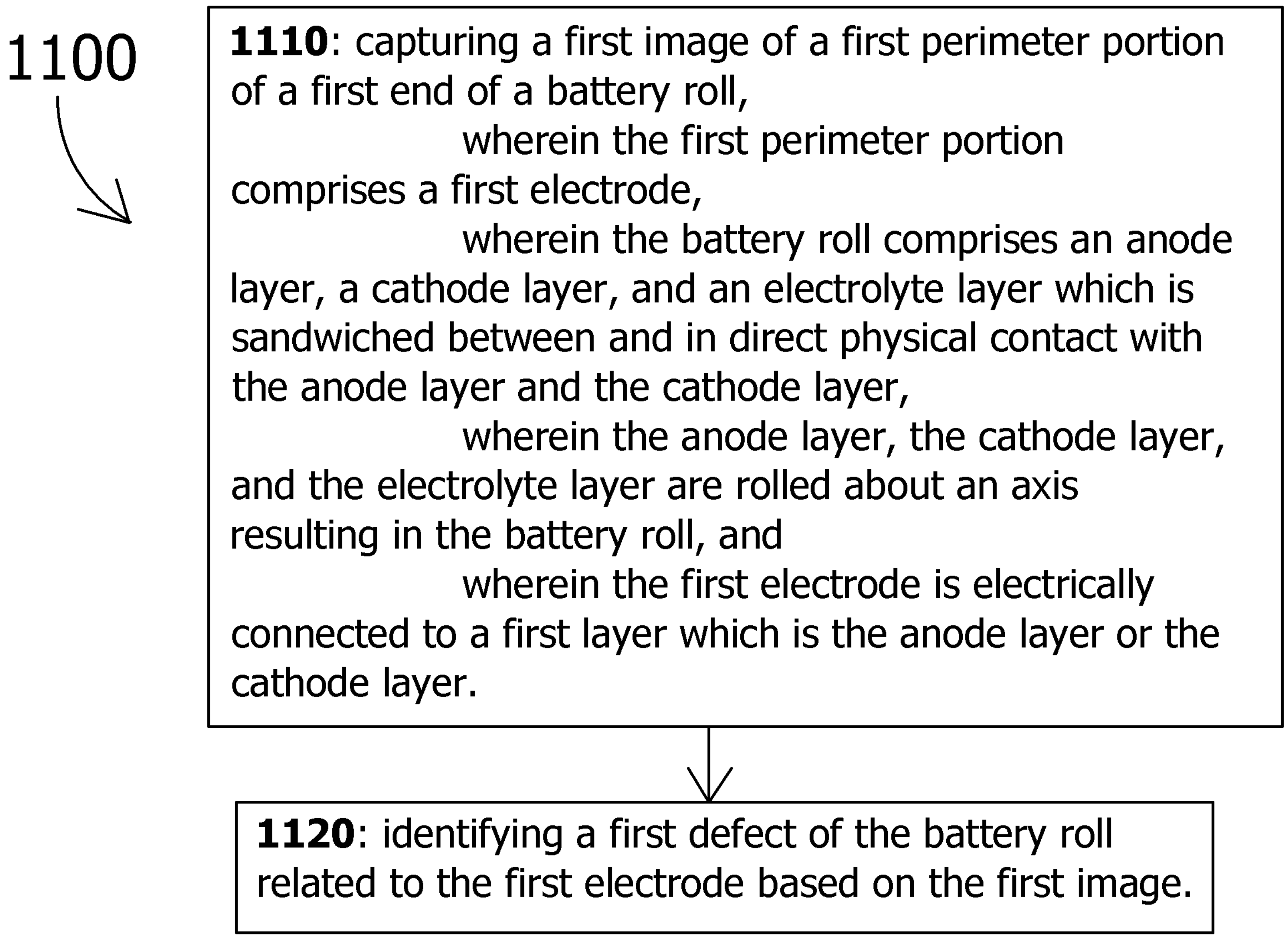
1100
1110: capturing a first image of a first perimeter portion of a first end of a battery roll,
wherein the first perimeter portion comprises a first electrode,
wherein the battery roll comprises an anode layer, a cathode layer, and an electrolyte layer which is sandwiched between and in direct physical contact with the anode layer and the cathode layer,
wherein the anode layer, the cathode layer, and the electrolyte layer are rolled about an axis resulting in the battery roll, and
wherein the first electrode is electrically connected to a first layer which is the anode layer or the cathode layer.
1120: identifying a first defect of the battery roll related to the first electrode based on the first image.

FIG. 11

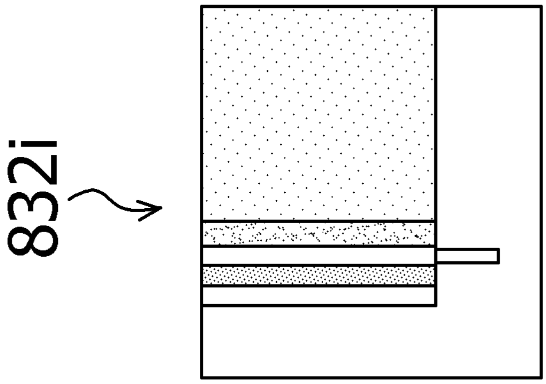

FIG. 12B

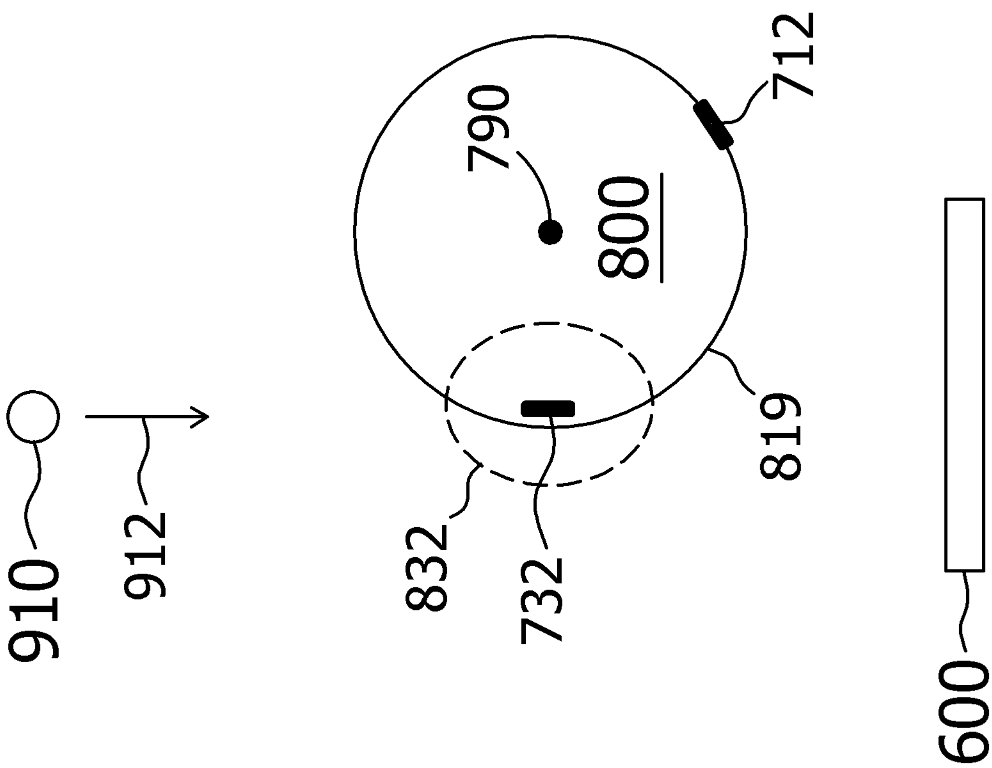

FIG. 12A

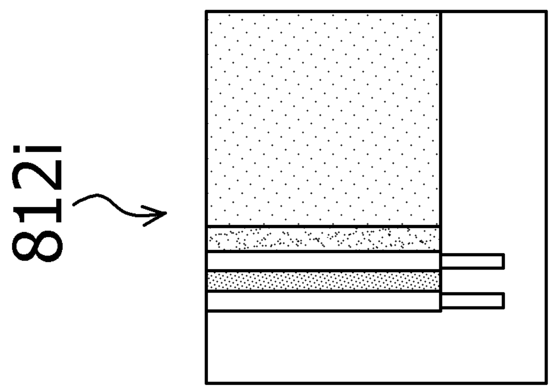

FIG. 13B

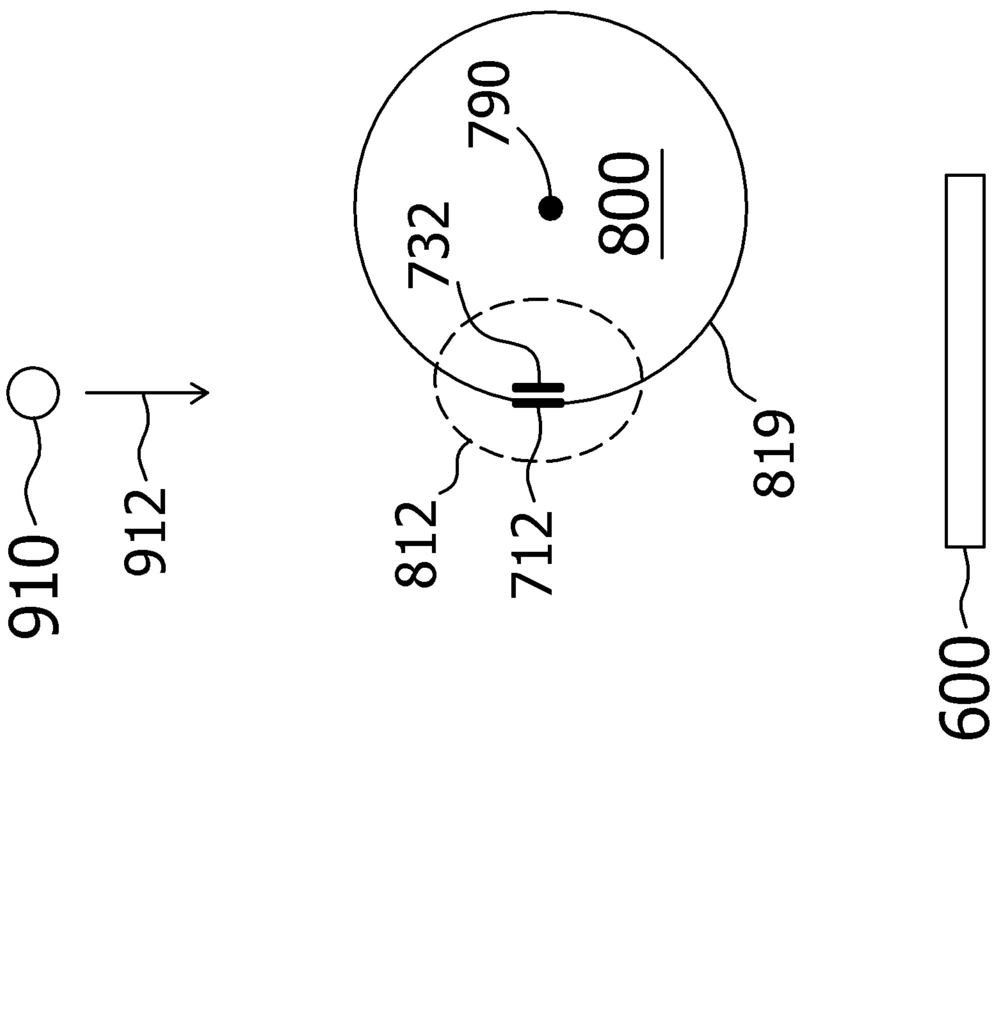

FIG. 13A

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2021/106361

A. CLASSIFICATION OF SUBJECT MATTER

G01N 23/04(2018.01)i

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)

G01N 23/-; G01B 15/-; H01M 10/-

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)

VEN;CNABS;CNTXT: battery, cell, tab, eletrode, roll+, lithium ion, imag+, x 1w ray, anode, cathode, electrolyte, portion, end, corner

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN 111403800 A (SHENZHEN DACHENG INTELLIGENT CONTROL TECH CO LTD) 10 July 2020 (2020-07-10) paragraphs [0025]-[0026] in the description and figures 2， 8	1-21
Y	CN 211789318 U (SHENZHEN DACHENG INTELLIGENT CONTROL TECH CO LTD) 27 October 2020 (2020-10-27) paragraphs [0094]-[0098] in the description and figures 2， 8	1-21
Y	CN 207850955 U (GUANGDONG ZHENGYE TECHNOLOGY CO LTD) 11 September 2018 (2018-09-11) paragraphs[0002]， [0018]， [0032]-[0033] in the description	1-21
Y	CN 108152305 A (GUANGDONG ZHENGYE TECHNOLOGY CO LTD) 12 June 2018 (2018-06-12) paragraphs[0002]， [0018]， [0032]-[0033] in the description	1-21
Y	CN 108008238 A (GUANGDONG ZHENGYE TECHNOLOGY CO LTD) 08 May 2018 (2018-05-08) paragraphs[0026]， [0039]-[0042] in the description	1-21

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 November 2021	**18 April 2022**

Name and mailing address of the ISA/CN	Authorized officer
National Intellectual Property Administration, PRC **6, Xitucheng Rd., Jimen Bridge, Haidian District, Beijing 100088, China**	**ZHOU,Honghui**
Facsimile No. **(86-10)62019451**	Telephone No. **(86-10)62089913**

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	CN 204479091 U (KUNSHAN EFD PREC INSTR CO LTD) 15 July 2015 (2015-07-15) paragraph [0016] in the description	1-21
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A	KR 20140013675 A (INNOMETRY CO) 05 February 2014 (2014-02-05) the whole document	1-21

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2021/106361

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CN	111403800	A	10 July 2020	None			
CN	211789318	U	27 October 2020	None			
CN	207850955	U	11 September 2018	None			
CN	108152305	A	12 June 2018	None			
CN	108008238	A	08 May 2018	None			
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				KR	20020085266	A	16 November 2002
				TW	523598	B	11 March 2003
				US	2002166802	A1	14 November 2002
				CN	1384364	A	11 December 2002
CN	101106203	A	16 January 2008	None			
KR	20210015329	A	10 February 2021	KR	102257982	B1	28 May 2021
KR	20140013675	A	05 February 2014	KR	101380858	B1	08 April 2014