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(54) **Title:** METHOD AND APPARATUS FOR PASTE PRODUCTION AND APPLICATION ON ELECTRODE SUBSTRATES FOR LEAD ACID BATTERIES

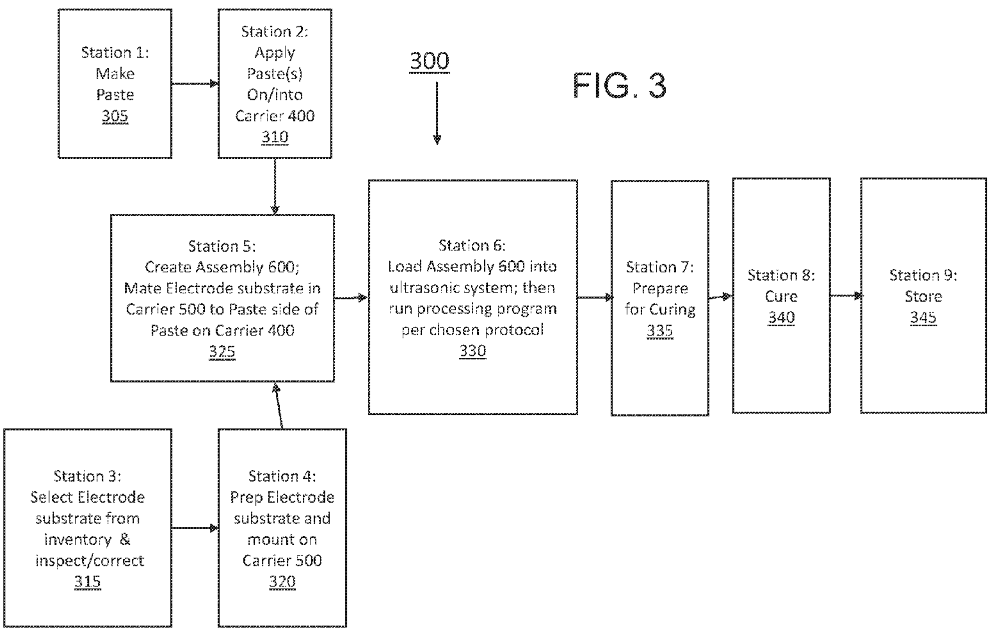

FIG. 3

(57) **Abstract:** A system to create a cell for a monopole or bipole lead acid battery includes a paster to produce wet paste, a first carrier structure to receive the wet paste, and a second carrier structure to receive an electrode substrate. A combining station combines the first carrier structure and corresponding wet paste and the second carrier structure and corresponding electrode substrate into an assembly. An ultrasonic welding system receives the assembly and provides mechanical pressure and ultrasonic energy to the assembly. A removal station via which to remove at least one of the first and second carrier structures to create a modified assembly.

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[Continued on next page]

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METHOD AND APPARATUS FOR PASTE PRODUCTION AND APPLICATION ON ELECTRODE SUBSTRATES FOR LEAD ACID BATTERIES

CLAIM OF PRIORITY

[0001] This U.S. Patent Application claims the benefit of U.S. Provisional Patent Application No. 63/432,926, filed December 15, 2022, entitled "Methods and Apparatuses for Paste Production and Application on Electrode Substrates for Lead Acid Batteries", the disclosure of which is incorporated by reference herein in its entirety.

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TECHNICAL FIELD

[0003] Embodiments of the invention generally to lead acid batteries, and in particular to methods and apparatuses for producing and applying paste to conductive electrode substrates for lead acid batteries.

BACKGROUND

[0004] With reference to FIGS. 1 and 2, lead acid batteries may be manufactured using monopolar or bipolar electrode substrates 100, 200. Positive and negative active material (PAM 210 and NAM 205) are each mixed into a paste, for example, a thixotropic paste, which is directly applied to a conductive electrode substrate 100, 200, or simply, electrode substrate 100, 200, or electrode 100, 200. For monopole batteries, using a grid type electrode substrate 100 is advantageous from the perspective of manufacturing. However, the flow of paste onto and/or around the grid may affect the volume of paste applied, may result in undesirable voids within the paste and may limit desirable intimate contact between the paste and electrode substrate. Similarly, for bipole batteries the interface between the paste 205 or paste 210 and the electrode substrate 200 may have voids and gaps. The performance and life of the battery is critically dependent upon the paste to electrode substrate interface. Pasting directly onto the electrode substrate provides better contact with the electrode substrate, which is a prerequisite for achieving a good corrosion layer in the curing and formation process.

[0005] There are challenges in applying paste in bipole electrodes. Traditional monopole pasting techniques cannot be easily adapted to bipole electrodes since different paste formulations are used on each side of the electrode. Furthermore, the mechanical forces used in monopole pasting processes may not be tolerated well by the electrode substrate. The use of external plates for active material, particularly for PAM 210, require higher pressures and increased planarity to achieve a good corrosion layer. It is difficult to formulate a paste that can meet the conflicting requirements of the applications. For monopole electrodes, even though the paste application process is well established, there is still room for improvement to purge voids and gaps that occur during the pasting process. Likewise, it is difficult to formulate a paste that can meet the conflicting requirements of the applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Embodiments are illustrated by way of example, and not by way of limitation, and will be more fully understood with reference to the following detailed description when considered in connection with the figures in which:

[0007] FIG. 1 is a diagram of a monopole battery.

[0008] FIG. 2 is a diagram of a bipole battery.

[0009] FIG. 3 is a flowchart of an exemplary manufacturing paste process.

[0010] FIG. 4A is a cross sectional view of a first carrier with paste.

[0011] FIG. 4B is a top view of the first carrier with paste.

[0012] FIG. 5A is a side view of a second carrier with an electrode substrate.

[0013] FIG. 5B is a top view of a second carrier with an electrode substrate.

[0014] FIG. 6 is a diagram of a first assembly combining the first and second carriers illustrated in FIGS. 4 and 5.

[0015] FIG. 7A is a diagram of an ultrasonic system.

[0016] FIG. 7B is a diagram of a first assembly loaded into the ultrasonic system illustrated in FIG. 7A in a first orientation.

[0017] FIG. 7C is a diagram of the first assembly loaded into the ultrasonic system illustrated in FIG. 7A in a second orientation.

[0018] FIG. 8 is a diagram of an ultrasonic system run protocol.

[0019] FIG. 9A is a diagram of a first assembly being prepared for curing without a mask.

[0020] FIG. 9B is a diagram of a first assembly being prepared for curing with a mask.

[0021] FIG. 10A is a diagram of an interface between paste and an electrode substrate before ultrasound system processing.

[0022] FIG. 10B is a diagram of an interface between paste and an electrode substrate after ultrasound system processing.

[0023] FIG. 11 is a diagram of a cross section of a second carrier with an electrode substrate.

[0024] FIG. 12 is a diagram of a second assembly with a modified second carrier mated with the top side of the first carrier with paste and a bottom side of the first carrier with paste.

[0025] FIG. 13A is a diagram of an ultrasonic system for dual side processing.

[0026] FIG. 13B is a diagram of an ultrasonic system for dual side processing loaded with the second assembly.

[0027] FIG. 14 is a SEM photograph of a tetra-base paste.

[0028] FIG. 15 is a SEM photograph of a tri-based paste.

[0029] FIG. 16 is a SEM photograph of a layered paste assembly.

[0030] FIG. 17 is an example of an electrode with layered pasting.

[0031] FIG. 18 is a block diagram of an exemplary process flow for layered pasting.

DETAILED DESCRIPTION

[0032] Embodiments of the invention generally improve the interface contact between the paste and the electrode substrate in monopole and bipole lead acid batteries. Embodiments employ methods in an electrode (plate) making manufacturing process that scale to high volume/low-cost production and improve paste formulations to enable superior adhesion and utilization of the active material.

[0033] Advantages of embodiments of the invention include an improved interface between the electrode substrate and the paste, resulting in an improved cycle life, reduced internal resistance, improved active material utilization including higher volumetric and gravimetric energy density, and improved dynamic charge acceptance enabled by paste filling of convoluted surfaces with high surface area.

[0034] With reference to FIG. 3, process steps 305-345 are associated with manufacturing workstations 1-9 depicted in the figure. The partitioning of various steps into separate workstations as depicted in FIG. 3 is one example of many possible permutations and arrangements. Some of the secondary issues associated with processing are not depicted in the drawings, such as non-stick non-porous layers for any materials touching the paste, inclusion of foam layers to fill voids between layers, etc. The process steps 305-345 are described below, station by station.

[0035] Station 1: A paster (a means of producing paste, either manually or automated) produces an amount of wet paste at step 305. The paste may be sectioned or segmented into desired dimensions.

[0036] Station 2: One or more sections or segments of paste are placed at step 310 into a first carrier structure, referred to herein as carrier 400. With reference to FIG. 4, carrier 400 may be a piece of paper, or a more complex structure. In different embodiments carrier 400 may provide different functions. One component and function of carrier 400 is a vertical portion 400A which allows for the lateral movement of paste 415 that may result from the combination of pressure and ultrasound energy. Vertical portion 400A limits the amount of lateral movement so it cannot exceed the dimensions of the cavity 420 defined by inside vertical surface of vertical portion 400A. Note that the vertical dimension y1 of vertical portion 400A is less than the vertical dimension y2 of paste 415. This allows force to be applied, for example, by an ultrasonic system, to paste 415 and limits the amount of vertical displacement of the paste. Another component and function of carrier 400 is a horizontal portion 400B that provides protection of the surface of the paste that is adjacent the horizontal portion 400B. Portion 400B comprises a material that does not adhere to the paste.

[0037] Station 3: An electrode substrate, e.g., electrode 100 or 200, to which the paste is to be applied, is first inspected and any debris or defects corrected at step 315.

[0038] Station 4: With reference to FIGS. 5A and 5B, the prepared electrode substrate 100, 200 is then placed into a second carrier, referred to herein as carrier 500, at step 320.

[0039] Station 5: Carrier 400 and Carrier 500 are positioned at step 325 so the paste 415 is brought into contact with the surface of electrode substrate 100, 200 to make assembly 600 depicted in FIG. 6

[0040] Station 6: an ultrasonic system 700, such as shown in FIG. 7A, provides the means of providing mechanical pressure and ultrasonic energy to assembly 600. In one embodiment, the ultrasonic system is a typical ultrasonic welder such as the Branson branded 2000X series of ultrasonic welders available from Sonitek Corporation. The ultrasonic system 700 comprises a base 701, a top 702, a converter 705 that converts electrical energy into mechanical vibration, a coupling and gain section (aka a booster) 710 that provides gain to the amplitude of vibration and couples it to a horn 715, for example, a block horn, that provides an appropriate X-Y distribution to engage with assembly 600, a means to provide pressure in the z-direction, e.g., an electric motor or actuator 720. Assembly 600 can be positioned in the ultrasonic system as shown in FIG. 7B. An alternative embodiment is to invert assembly 600 and position it in the ultrasonic system as shown in FIG. 7C. In either case once assembly 600 is positioned in the ultrasonic system 700, then ultrasound energy and mechanical pressure is applied to assembly 600 per a desired protocol at step 330 that specifies the pressure, ultrasound frequency, power and amplitude of the ultrasound as a function of time, for example, as depicted in the graph 800 in FIG. 8.

[0041] Station 7: after assembly 600 has been processed at station 6, it is moved to station 7 to prepare for curing, at step 335. The operations 335 performed at station 7 depend on the type of carrier 400 used. FIG. 9A depicts the removal of carrier 400 to create a modified assembly 905. FIG. 9B depicts portion 400A of carrier 400 left remaining in assembly 905 to act as a mask 900A for minimizing the effects of paste shedding that can occur in battery cycling. In alternative embodiments, carrier 500 may also or alternatively be removed.

[0042] Stations 8 and 9: the modified assembly 905 is placed in an oven to be cured at step 340, after which it can be stored at step 345.

[0043] According to embodiments of the invention, the exemplary manufacturing paste process depicted in the flowchart 300 of FIG. 3 may be a manual or batch process. However, high-volume processing may use a continuous in-line automated flow through each operation. Additionally, a flash dryer process step may be included for stacking assemblies prior to curing/drying. Such a step may be performed after the electrode substrate and paste are connected, so that the exposed surface can be partially dried before it is placed into the ultrasonic system. This assumes that the electrode substrate side of the paste after flash drying is still wet enough to make solid contact with the electrode substrate.

[0044] By applying ultrasound and mechanical pressure to assembly 600 the resultant movement at a microscopic level allows the paste to fill in the gaps 1000 visible at 1000 between the paste and the electrode as shown in FIG. 10A so that no gaps exist, as depicted in FIG. 10B.

[0045] The ability to fill in gaps (small or large) creates a new opportunity to intentionally create contoured and/or roughened substrate surfaces that result in increasing the effective area between the electrode substrate 100, 200 and the paste 415. This not only improves adhesion at the interface between paste and substrate but it provides a greater diversity of ionic and electron flow. This diversity improves performance, e.g., reduced impedance, increased utilization of the paste.

[0046] The previously described processing method only applies to one side of the electrode substrate. In some bipolar applications it may be adequate to just process the PAM 210 paste, for example, with a standalone NAM plate in use. However, it is appreciated that for other applications both sides (the PAM side and the NAM side) of the bipole electrode may be treated.

[0047] In addition, above-described methods are applicable to pasting for monopole electrodes. Currently, monopole electrodes use a grid type electrode substrate 100. In one embodiment the pasted monopole electrodes, produced by a standard monopole pasting machine, is placed into an ultrasonic system with pressure and ultrasonic energy is applied to one or both sides of a monopole electrode substrate depending on the penetration of the ultrasonic energy. In another embodiment the monopole processing is the same as described herein for dual side processing of a bipole electrode, however in this case, both sides are either pasted with NAM 205 or both sides are pasted with PAM 210.

[0048] FIG. 11 shows a modified version 1100 of carrier 500 that enables the placement of paste 415 on both sides A and B of the electrode substrate 100, 200. The combined assembly 1200, depicted in FIG. 12, is suitable for dual sided processing. For a bipole electrode the paste 415 comprises PAM 210 on one side, e.g., the top side, and NAM 205 on the other side, e.g., the bottom side, of the electrode substrate 200. For a monopole electrode 100 the paste 415 comprises PAM 210 on both top and bottom sides or NAM 205 on both top and bottom sides, depending on the combined assembly 1200 being positive or negative respectively.

[0049] FIG. 13A shows an ultrasonic system which can apply ultrasonic energy from above and below the location for placing assembly 1200. In ultrasonic system 1300, mechanical pressure and ultrasonic energy is applied to assembly 1200. The ultrasonic system 1300 comprises a base 1301, a top 1302, and in each, a converter 1305 that converts electrical energy into mechanical vibration, a coupling and gain section (aka a booster) 1310 that provides gain to the amplitude of vibration and couples it to a horn 1315, for example, a block horn, that provides an appropriate X-Y distribution to engage with assembly 1200, a means to provide pressure in the z-direction, e.g., an electric motor or actuator 1320. Assembly 1300 can be positioned in the ultrasonic system as shown in FIG. 13B. An alternative embodiment is to invert assembly 1200 and position it in the ultrasonic system, similar to as described above with reference to FIG. 7C. In either case once assembly 1200 is positioned in the ultrasonic system 1300, then ultrasound energy and mechanical pressure is applied to assembly 1200 per a desired protocol that specifies the pressure, ultrasound frequency, power and amplitude of the ultrasound as a function of time, for example, as depicted in the graph 800 in FIG. 8.

[0050] Additional embodiments of the invention involve a new method and associated apparatuses that use multiple layers of paste rather than a single layer of paste. The above described embodiments enable these additional embodiments because the above described embodiments do not mix the layers of paste, since the joining of the layers of paste is accomplished by application of pressure perpendicular to the plane of the electrode substrate together with the application of ultrasonic energy.

[0051] The use of only a single layer of paste is well known in the art. Paste is formulated to best address the needs of the application. However, those needs may be conflicting from the perspective of paste formulation, e.g., for example, a paste that has good adhesion may not have good energy capacity, or durability. Therefore, prior art paste formulation is a compromise. The below described embodiments can use multiple layers of paste to optimize the performance of a battery for the specific application without compromising performance.

[0052] One of the below described embodiments relates to layered PAM paste 210 formulations, while another relates to layered NAM paste 205 formulations. Both embodiments relate to the above-described embodiments and the processing steps/equipment discussed in FIGS. 3-13B but modified to accommodate the paste assemblies in the below described embodiments.

[0053] According to the following embodiments, improved battery performance is achieved by layering pastes made possible because of physical locations of failure mechanisms. For example, a corrosion layer forms between the electrode substrate and the paste. The inability of forming a good corrosion layer is a common failure mechanism in bipolar lead acid batteries. It is therefore advantageous to use a first layer of paste (layer in contact with the electrode substrate) that provides good adhesion to the electrode substrate. As another example, shedding or flaking of paste is known to lead to soft shorts within a battery cell, i.e., such shedding or flacking creates a current leakage path. It is therefore advantageous to use a second layer of paste that provides good cohesion properties on top of the first layer of paste.

[0054] According to one embodiment related to layered PAM formulations, the composition and structure of layered PAM pastes is improved. Traditionally PAM paste contains lead sulfate which is either tetra-basic or tri-basic. Tetra-basic paste, a SEM photo of which is provided at 1400 in FIG. 14, has the advantages of stronger paste, e.g., better cohesion, and a better cycle life. Tri-basic paste, a SEM photo of which is provided at 1500 in FIG. 15, has advantages of better utilization and higher capacity. Therefore, in one embodiment the paste is layered, such that the first layer (layer in contact with the electrode substrate) is tri-basic and the second layer is tetra-basic, a SEM photo of which is provided at 1600 in FIG. 16. This embodiment is suitable for deep cycle batteries, having high capacity and better cycle life. FIG. 17 provides a block diagram 1700 of a first layer of tri-basic sulfate paste 1705 and a second layer of tetra-basic sulfate paste 1710, both atop an electrode substrate 100, 200.

[0055] According to one embodiment related to layered NAM formulations, NAM does not have the corrosion layer problem that PAM does. However, charge acceptance can be improved by a layered approach to the NAM paste. The first layer of paste, in contact with the electrode substrate, is designed to have a high discharge capacity, whereas the second layer is designed to have high charge acceptance.

[0056] These embodiments modify the process flow described earlier in FIG. 3, as depicted in the modified process flow 1800 depicted in FIG. 18, where two or more pastes are layered immediately onto carrier 400. With reference to FIG. 18, process steps 1805-1845 are associated with manufacturing workstations 1-9 depicted in the figure. The partitioning of various steps into separate workstations as depicted in FIG. 18 is one example of many possible permutations and arrangements. Some of the secondary issues associated with processing are not depicted in the drawings, such as non-stick non-porous layers for any materials touching the paste, inclusion of foam layers to fill voids between layers, etc. The process steps 1805-1845 are described below, station by station.

[0057] Station 1A: A paster (a means of producing paste, either manually or automated) produces an amount of wet paste at step 1805A for a first a layer of paste. The first layer of paste may be sectioned or segmented into desired dimensions.

[0058] Station 1B: A paster (a means of producing paste, either manually or automated) produces an amount of wet paste at step 1805B for a second layer of paste. The second paste may be sectioned or segmented into desired dimensions.

[0059] Station 2: One or more sections or segments of multiple layers of paste are applied, sequentially, at step 1810 into a first carrier structure, much like the carrier 400 described above. In different embodiments carrier 400 may provide different functions. One component and function of carrier 400 is a vertical portion 400A which allows for the lateral movement of layers of paste that may result from the combination of pressure and ultrasound energy. Vertical portion 400A limits the amount of lateral movement so it cannot exceed the dimensions of the cavity 420 defined by inside vertical surface of vertical portion 400A. Note that the vertical dimension y1 of vertical portion 400A is less than the vertical dimension y2 of the layers of paste. This allows force to be applied, for example, by an ultrasonic system, to multiple layers of paste and limits the amount of vertical displacement of the layers of paste. Another component and function of carrier 400 is a horizontal portion 400B that provides protection of the surface of the first layer of paste that is adjacent the horizontal portion 400B. Portion 400B comprises a material that does not adhere to the first layer of paste.

[0060] Station 3: An electrode substrate, e.g., electrode 100 or 200, to which the layers of paste are to be sequentially applied, is first inspected and any debris or defects corrected at step 1815.

[0061] Station 4: With reference to FIG. 5, the prepared electrode substrate 100, 200 is then placed into a second carrier, referred to herein as carrier 500, at step 1820.

[0062] Station 5: Carrier 400 and Carrier 500 are positioned at step 1825 so the layers of paste are brought into contact with the surface of electrode substrate 100, 200 to make assembly 1700 depicted in FIG. 17.

[0063] Station 6: an ultrasonic system 700, such as shown in FIG. 7A, provides the means of providing mechanical pressure and ultrasonic energy to assembly 1700. In one embodiment, the ultrasonic system is a typical ultrasonic welder such as the Branson branded 2000X series of ultrasonic welders available from Sonitek Corporation. The ultrasonic system 700 comprises a base 701, a top 702, a converter 705 that converts electrical energy into mechanical vibration, a coupling and gain section (aka a booster) 710 that provides gain to the amplitude of vibration and couples it to a horn 715, for example, a block horn, that provides an appropriate X-Y distribution to engage with assembly 600, a means to provide pressure in the z-direction, e.g., an electric motor or actuator 720. Assembly 1700 can be positioned in the ultrasonic system as shown in FIG. 7B. An alternative embodiment is to invert assembly 1700 and position it in the ultrasonic system as shown in FIG. 7C. In either case once assembly 1700 is positioned in the ultrasonic system 700, then ultrasound energy and mechanical pressure is applied to assembly 1700 per a desired protocol at step 1830 that specifies the pressure, ultrasound frequency, power and amplitude of the ultrasound as a function of time, for example, as depicted in the graph 800 in FIG. 8.

[0064] Station 7: after assembly 1700 has been processed at station 6, it is moved to station 7 to prepare for curing. The operations performed at step 1835 depend on the type of carrier 400 used. FIG. 9A depicts the removal of carrier 400 to create a modified assembly 905 with one layer of paste. It is appreciated the modified assembly may include two layers of paste according to this embodiment. FIG. 9B depicts portion 400A of carrier 400 left remaining in assembly 905 to act as a mask 900A for minimizing the effects of paste shedding that can occur in battery cycling.

[0065] Stations 8 and 9: the modified assembly 905, with two layers according to this embodiment, is placed in an oven to be cured at step 1840, after which it can be stored at step 1845.

[0066] Another embodiment introduces the second layer of paste after the first layer has received one application of ultrasound. The second layer is then added to the first layer and a second application of ultrasound in completed.

[0067] Yet another embodiment applies ultrasound to the layered pastes before they are integrated with carrier 500. The intention with this embodiment is to secure the layers to themselves and then secure the composited layers to the electrode with a second ultrasound application.

CLAIMS

What is claimed is:

1. A system for creating a cell for a monopole or bipole lead acid battery, comprising:

a paster to produce wet paste;

a first carrier structure to receive the wet paste;

a second carrier structure to receive an electrode substrate;

a combining station at which to combine the first carrier structure and corresponding wet paste and the second carrier structure and corresponding electrode substrate into an assembly;

an ultrasonic welding system to receive the assembly and provide mechanical pressure and ultrasonic energy to the assembly; and

a removal station via which to remove at least one of the first and second carrier structures to create a modified assembly.

2. The system of claim 1,

wherein the paster to produce wet paste comprises a paster to produce a first layer of wet paste and a second layer of wet paste different than the first layer of wet paste;

wherein the first carrier structure to receive the wet paste comprises a carrier structure to receive the first layer of paste;

the system further comprising a third carrier structure to receive the second layer of wet paste;

wherein the combining station at which to combine the first carrier structure and corresponding wet paste and the second carrier structure and corresponding electrode substrate into an assembly comprises the combining station at which to combine the first carrier structure and corresponding first layer of wet paste, the third carrier structure and the corresponding second layer of wet paste, and the second carrier structure and corresponding electrode substrate into the assembly.

3. A method for creating a cell for a monopole or bipole lead acid battery, comprising:

producing, via a paster, a wet paste;

receiving at a first carrier structure the wet paste;

receiving at a second carrier structure an electrode substrate;

combining at a combining station the first carrier structure and corresponding wet paste and the second carrier structure and corresponding electrode substrate into an assembly;

applying mechanical pressure and ultrasonic energy via an ultrasonic welding system to the assembly; and

removing via a removing station at least one of the first and second carrier structures to create a modified assembly.

4. The method of claim 3,

wherein producing, via the paster, the wet paste comprises producing, via the paster, a first layer of wet paste and a second layer of wet paste different than the first layer of wet paste;

wherein receiving at the first carrier structure the wet paste comprises receiving at the carrier structure first layer of paste;

the method further comprising receiving via the third carrier structure the second layer of wet paste;

wherein combining at the combining station the first carrier structure and corresponding wet paste and the second carrier structure and corresponding electrode substrate into an assembly comprises combining at the combining station the first carrier structure and corresponding first layer of wet paste, the third carrier structure and the corresponding second layer of wet paste, and the second carrier structure and corresponding electrode substrate into the assembly.

FIG. 1

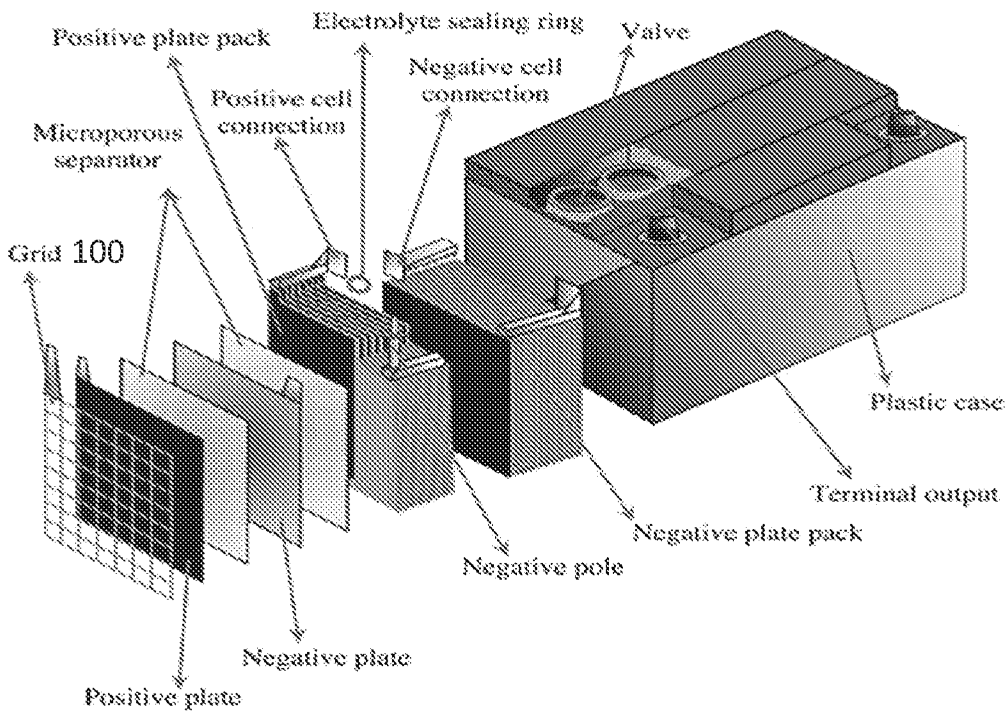
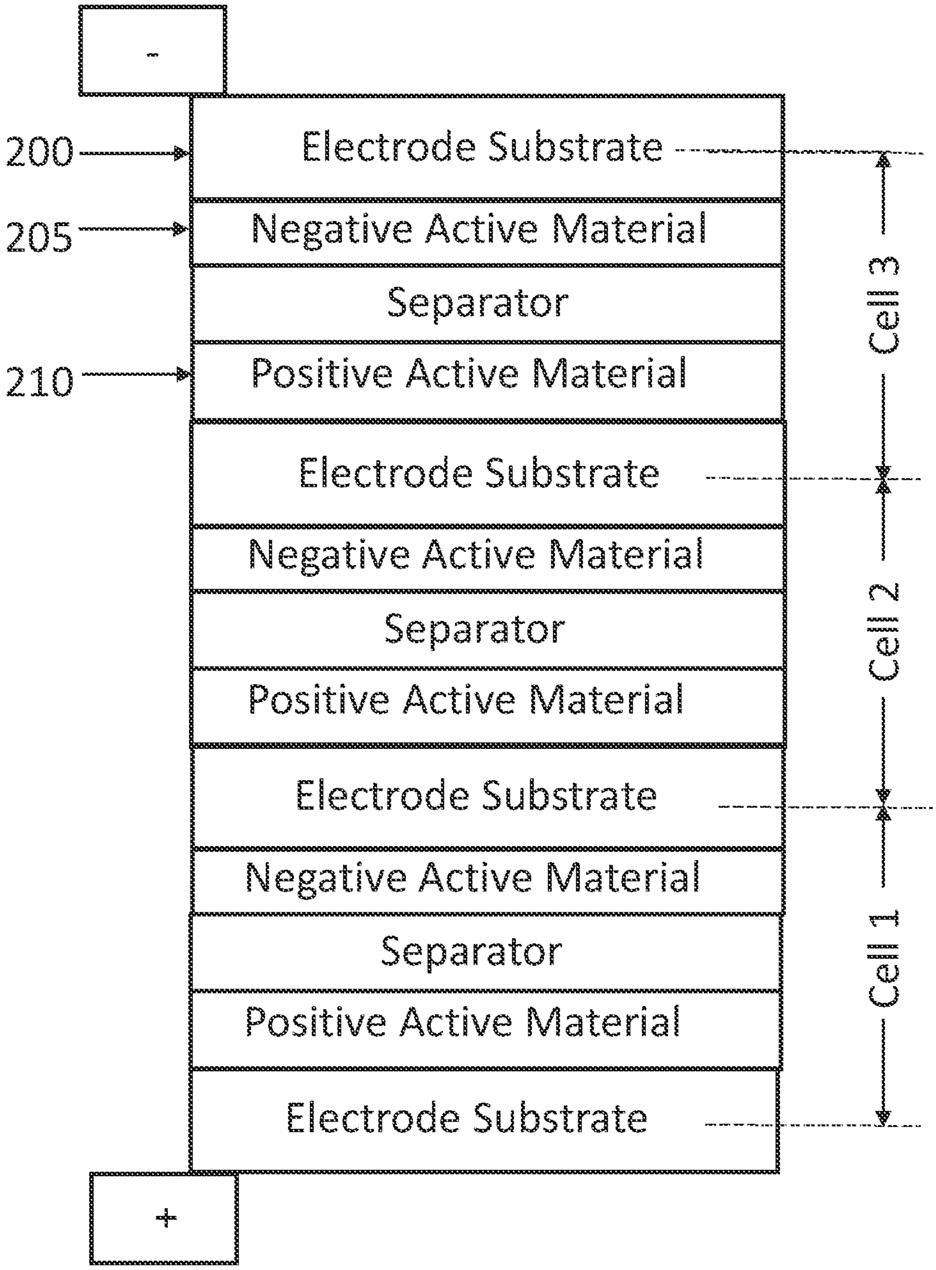

Positive plate pack
Electrolyte sealing ring
Valve
Negative cell connection
Positive cell connection
Microporous separator
Grid 100
Plastic case
Terminal output
Negative plate pack
Negative pole
Negative plate
Positive plate

FIG. 2


-
200
205
210
Electrode Substrate
Negative Active Material
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Positive Active Material
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Separator
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Electrode Substrate
Cell 3
Cell 2
Cell 1
+

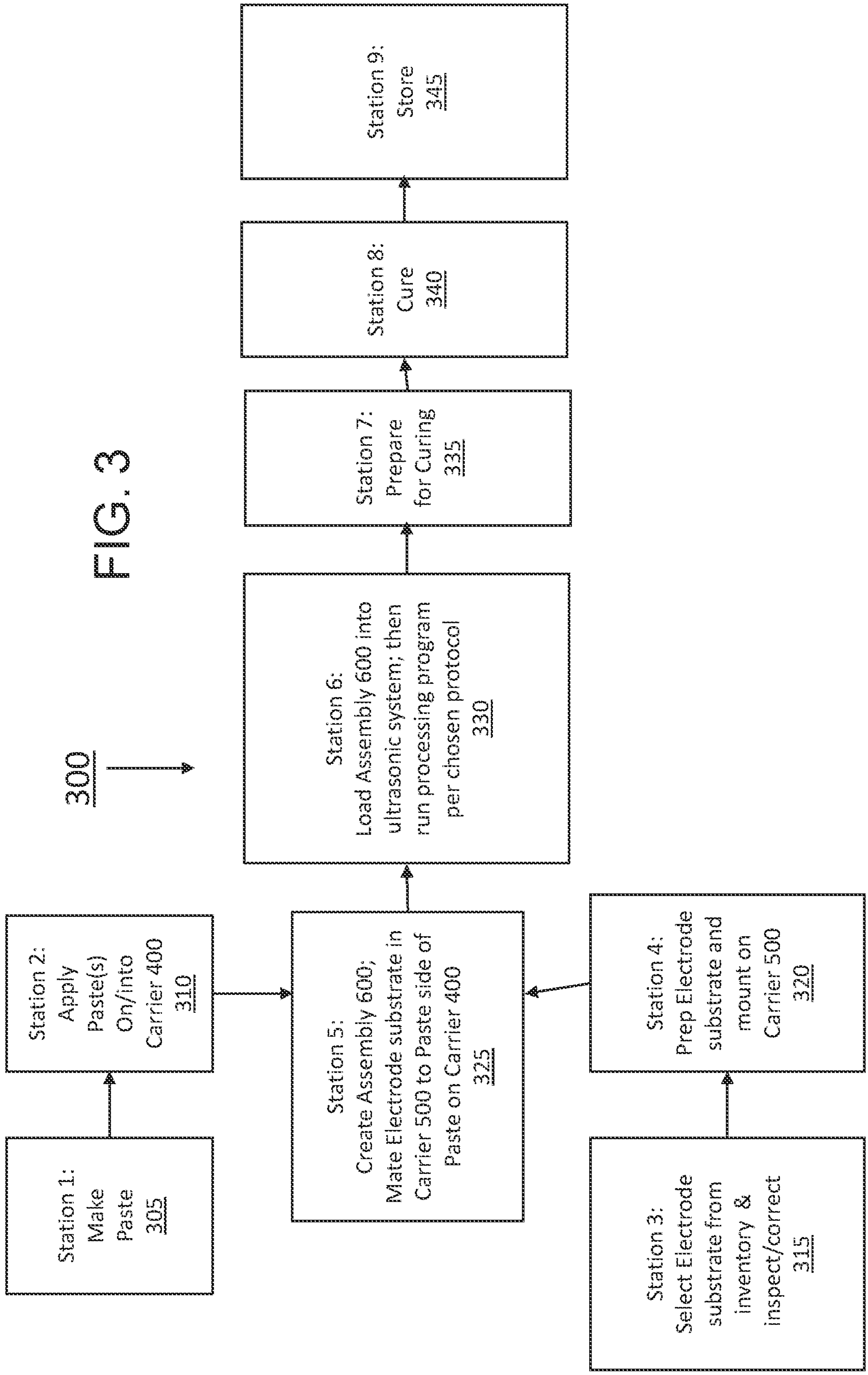
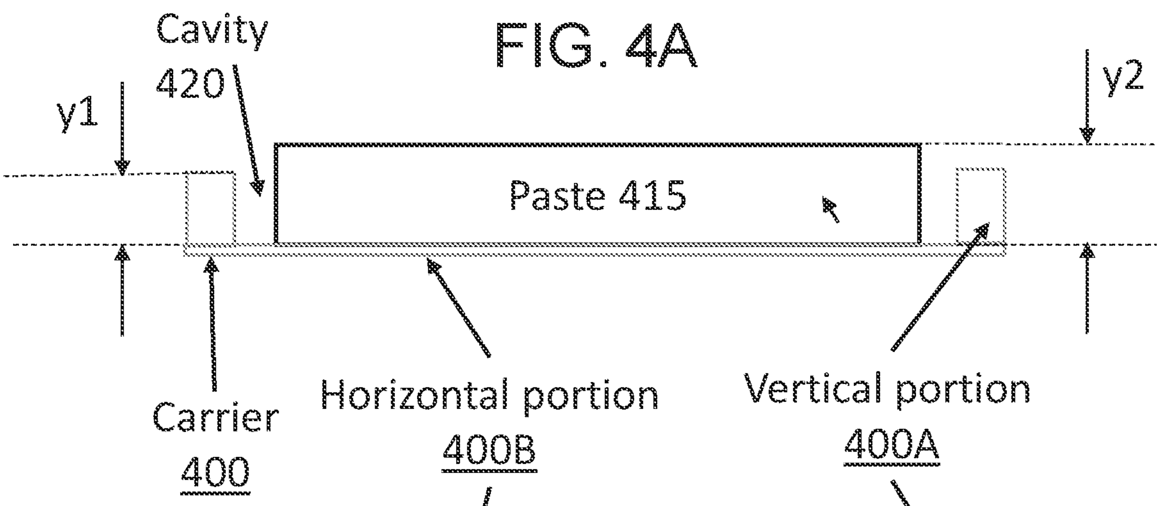

300
Station 1: Make Paste 305
Station 2: Apply Paste(s) On/into Carrier 400 310
Station 3: Select Electrode substrate from inventory & inspect/correct 315
Station 4: Prep Electrode substrate and mount on Carrier 500 320
Station 5: Create Assembly 600; Mate Electrode substrate in Carrier 500 to Paste side of Paste on Carrier 400 325
Station 6: Load Assembly 600 into ultrasonic system; then run processing program per chosen protocol 330
Station 7: Prepare for Curing 335
Station 8: Cure 340
Station 9: Store 345

FIG. 3

FIG. 4A


Cavity
420
y1
y2
Paste 415
Carrier
400
Horizontal portion
400B
Vertical portion
400A

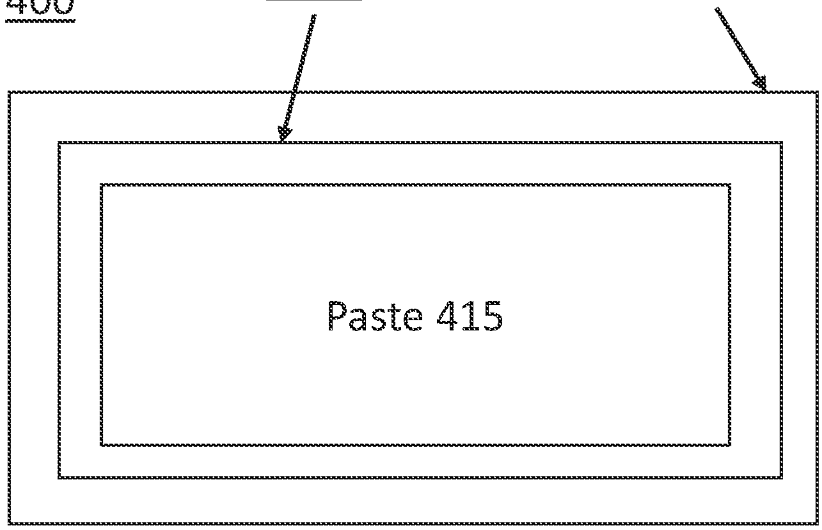

Paste 415

FIG. 4B

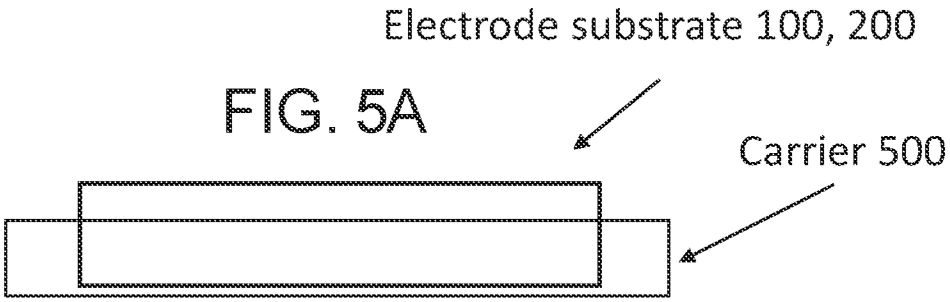

Electrode substrate 100, 200
Carrier 500

FIG. 5A

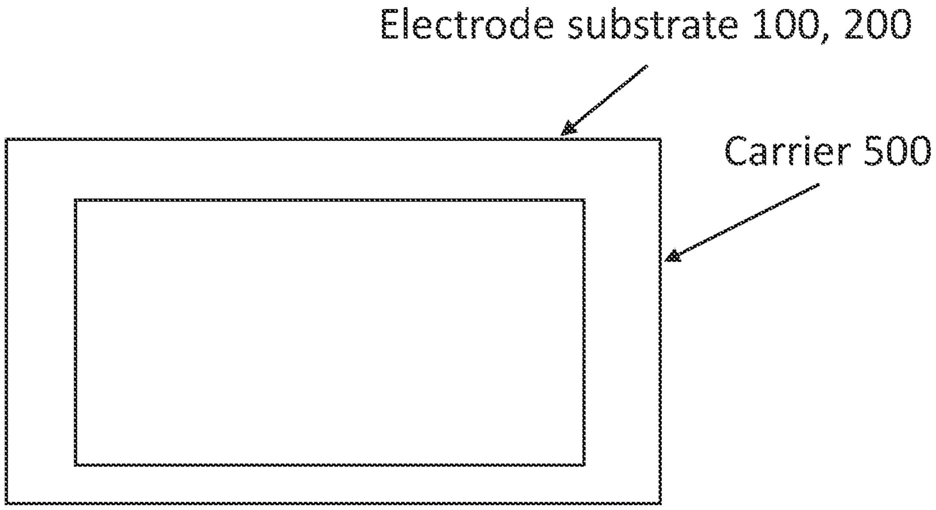

Electrode substrate 100, 200
Carrier 500

FIG. 5B

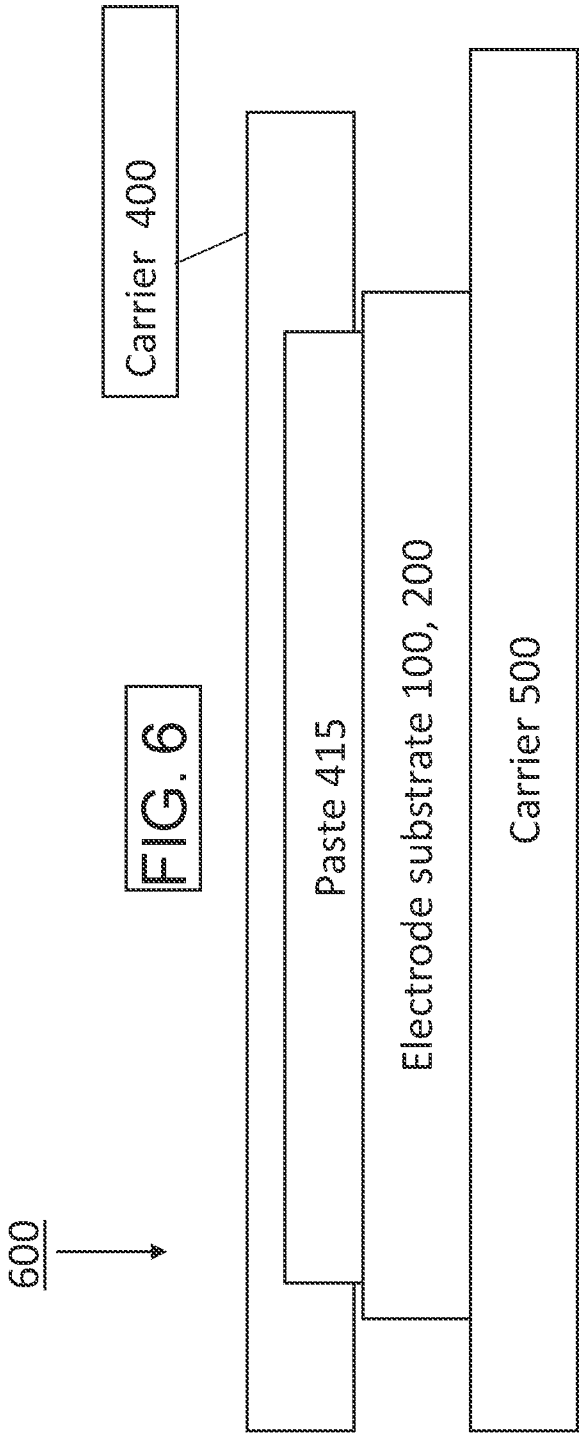

Carrier 400
Paste 415
Electrode substrate 100, 200
Carrier 500
600

FIG. 6

FIG. 7A

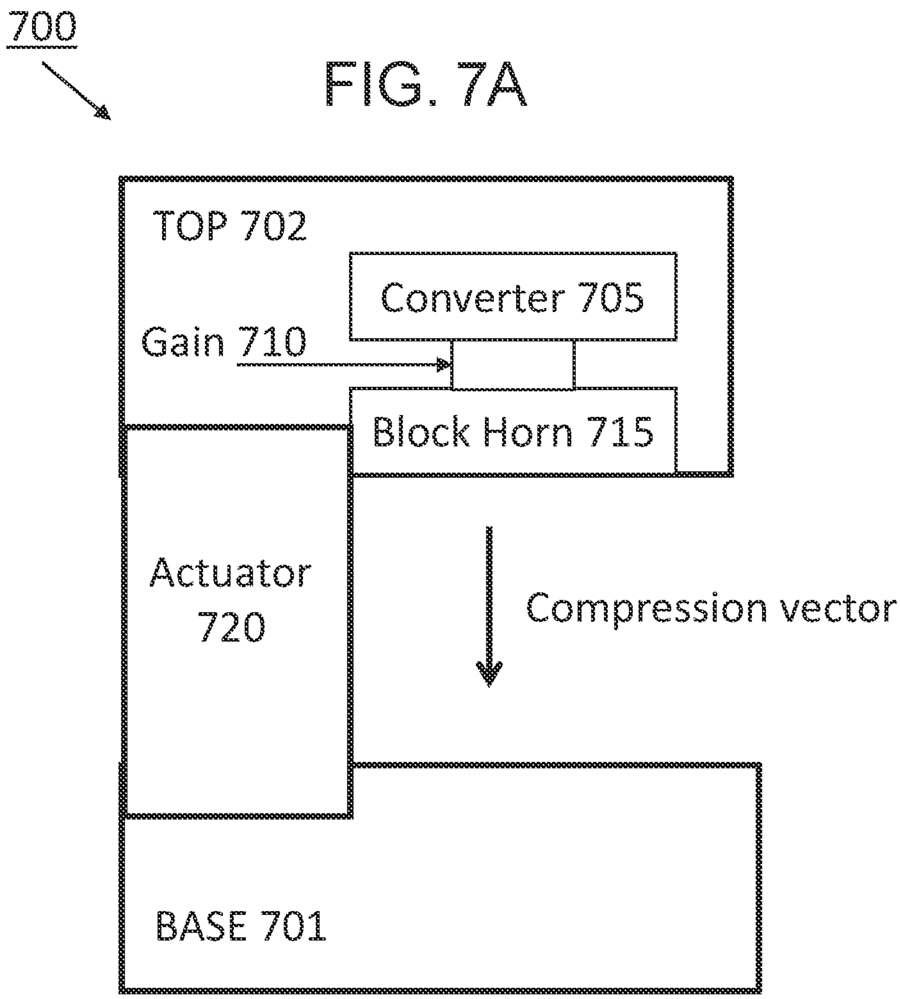

700
TOP 702
Converter 705
Gain 710
Block Horn 715
Actuator
720
Compression vector
BASE 701

FIG. 7B

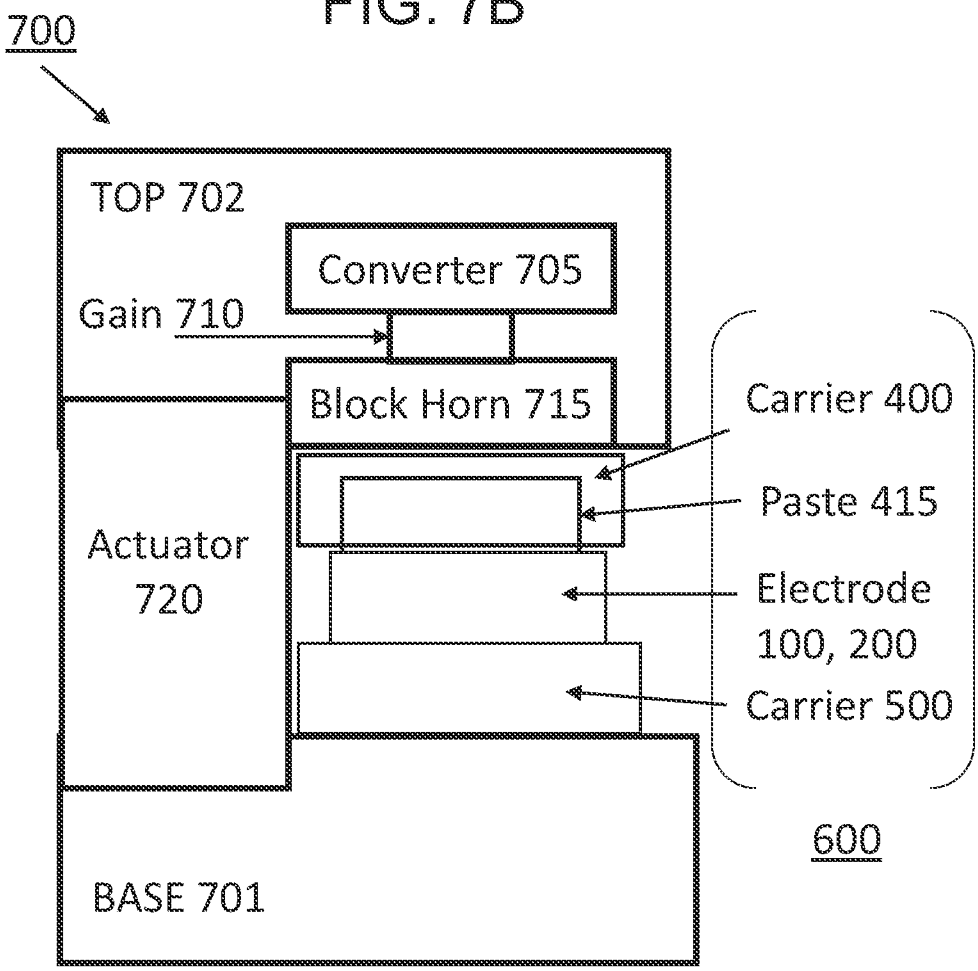
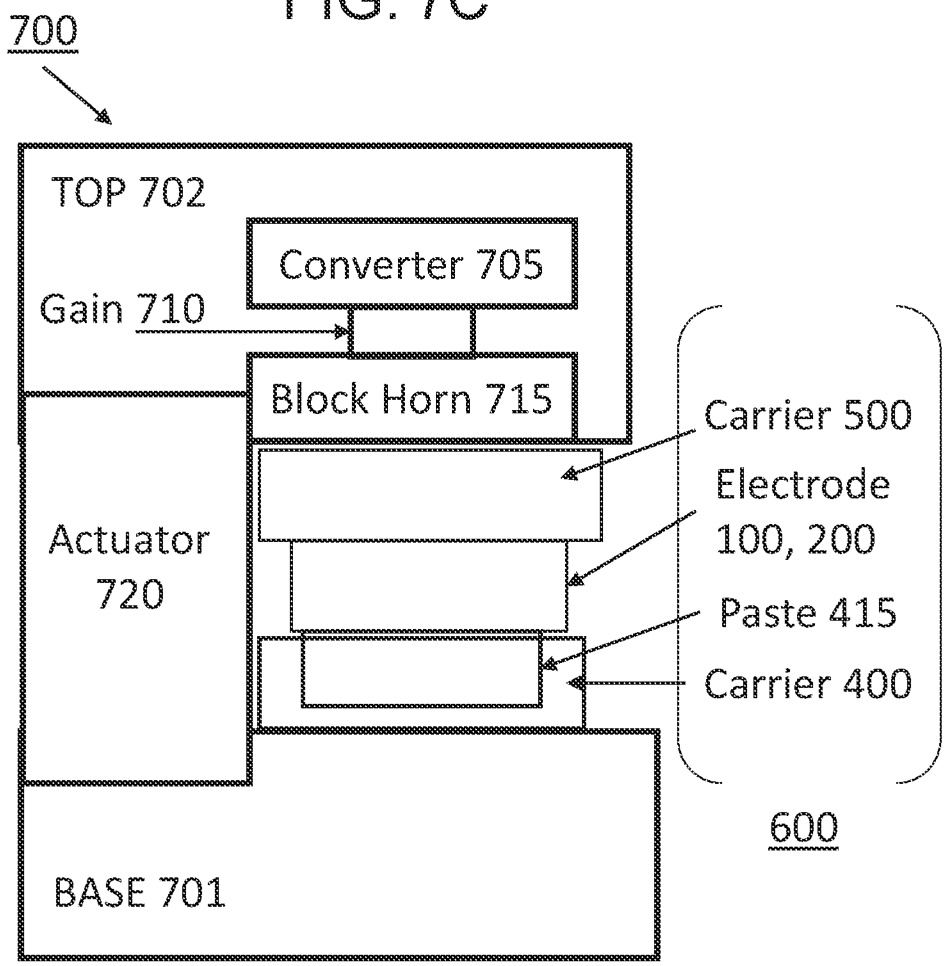

700
TOP 702
Converter 705
Gain 710
Block Horn 715
Actuator
720
BASE 701
Carrier 400
Paste 415
Electrode
100, 200
Carrier 500
600

FIG. 7C


700
TOP 702
Converter 705
Gain 710
Block Horn 715
Actuator 720
Carrier 500
Electrode 100, 200
Paste 415
Carrier 400
600
BASE 701

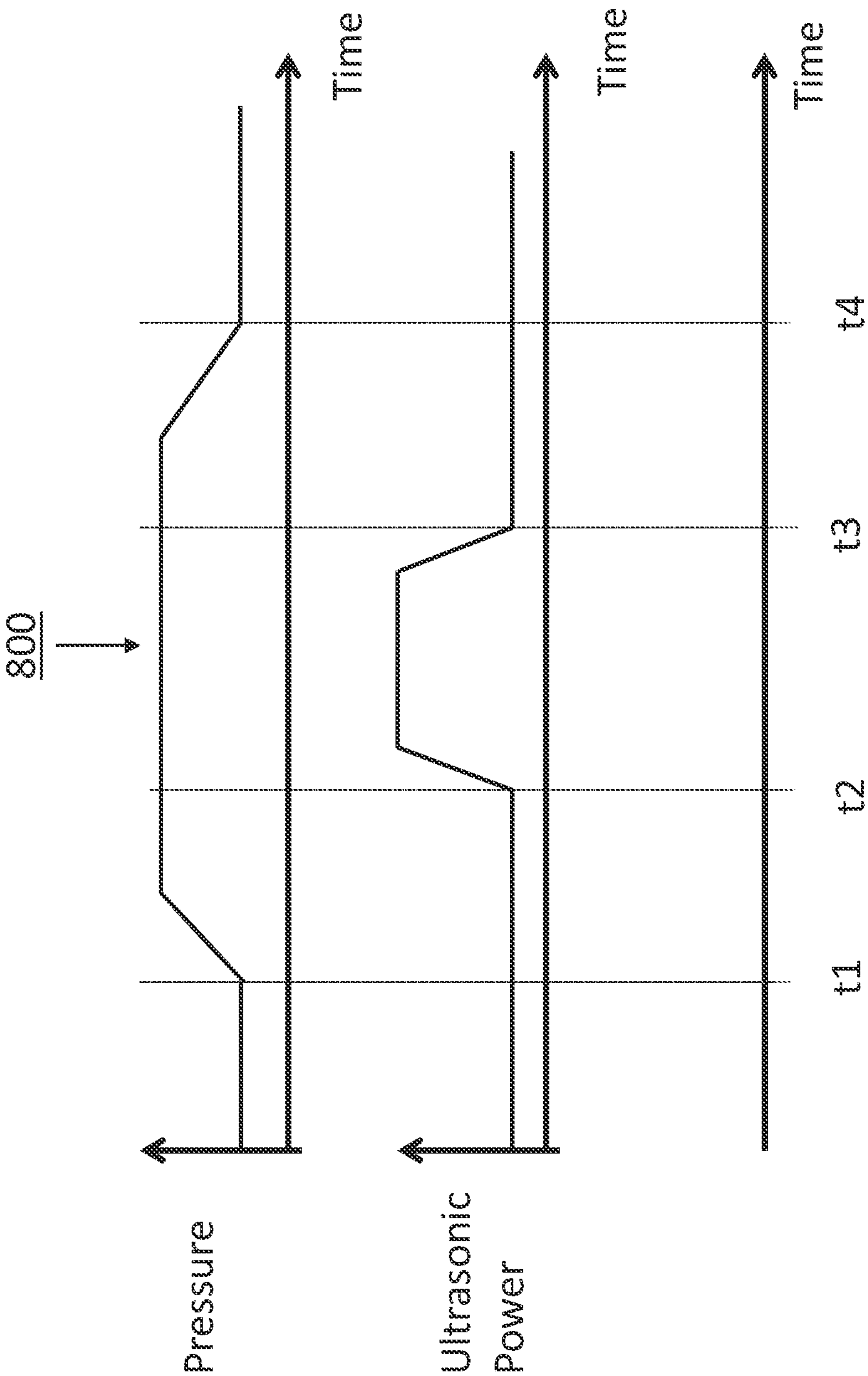
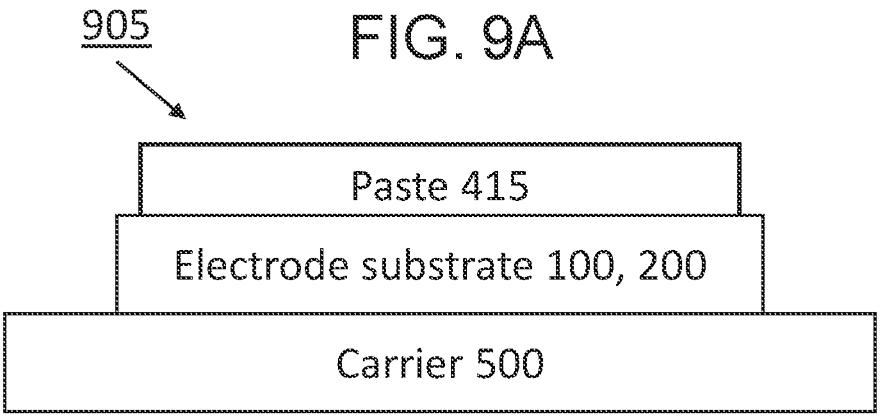
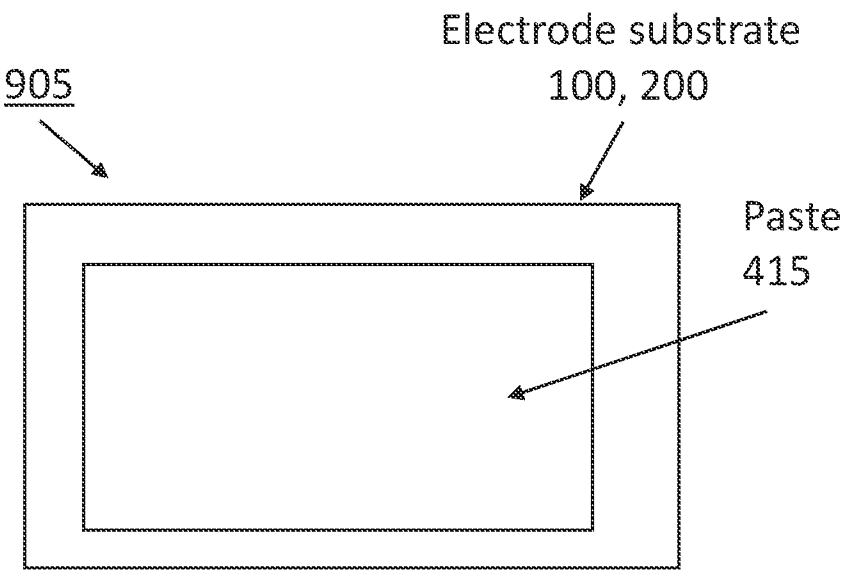


FIG. 8

FIG. 9A

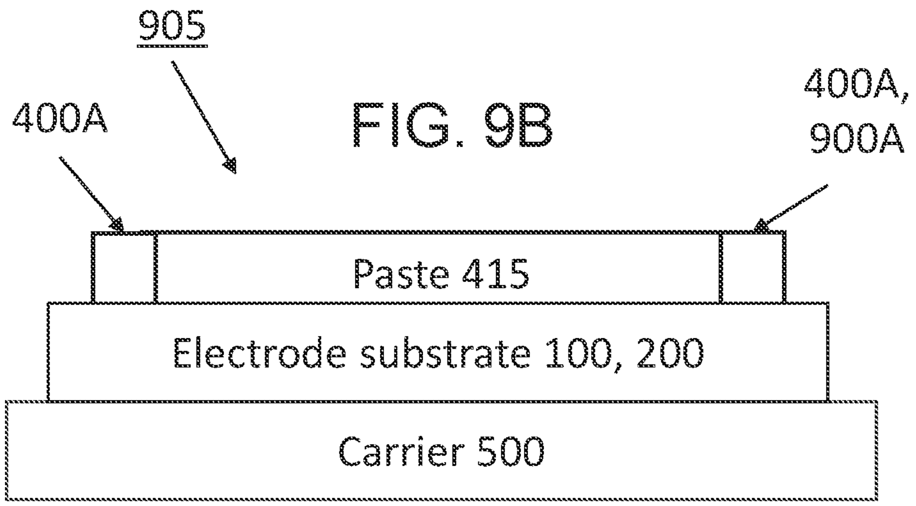


600 – SIDE VIEW

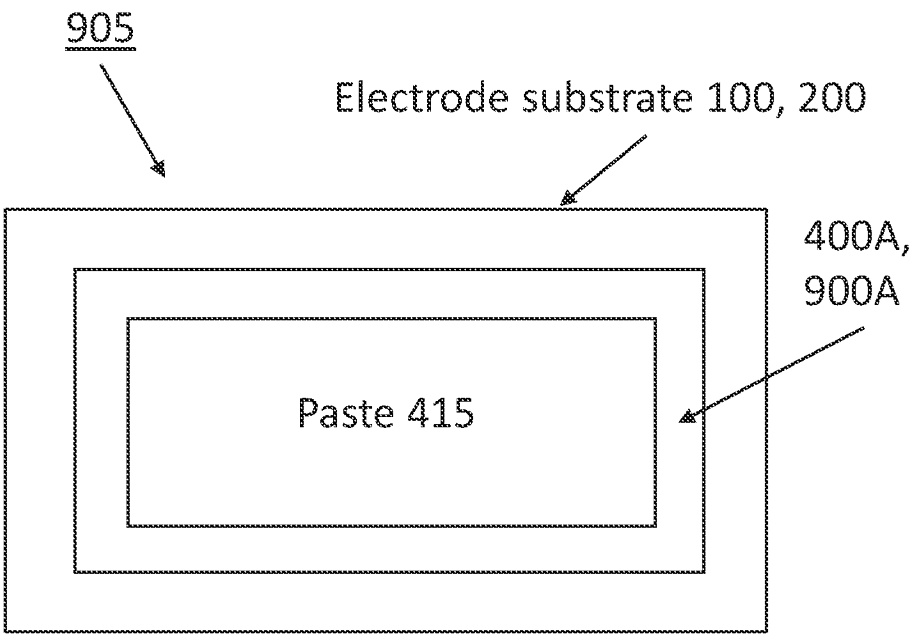


600 – TOP VIEW

FIG. 9B



600 – SIDE VIEW



600 – TOP VIEW

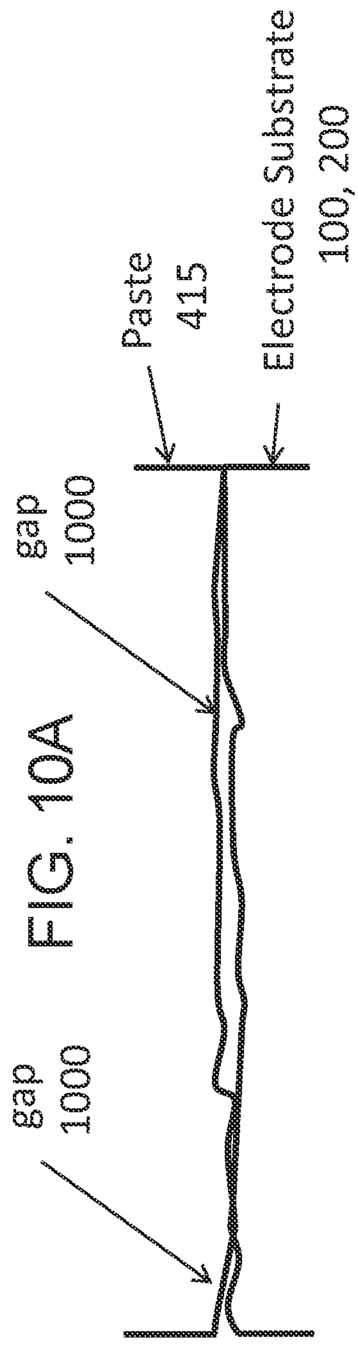


FIG. 10A

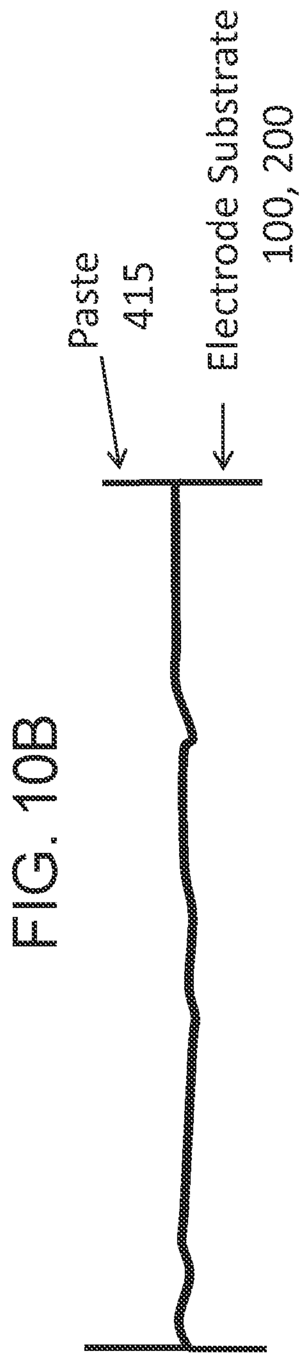
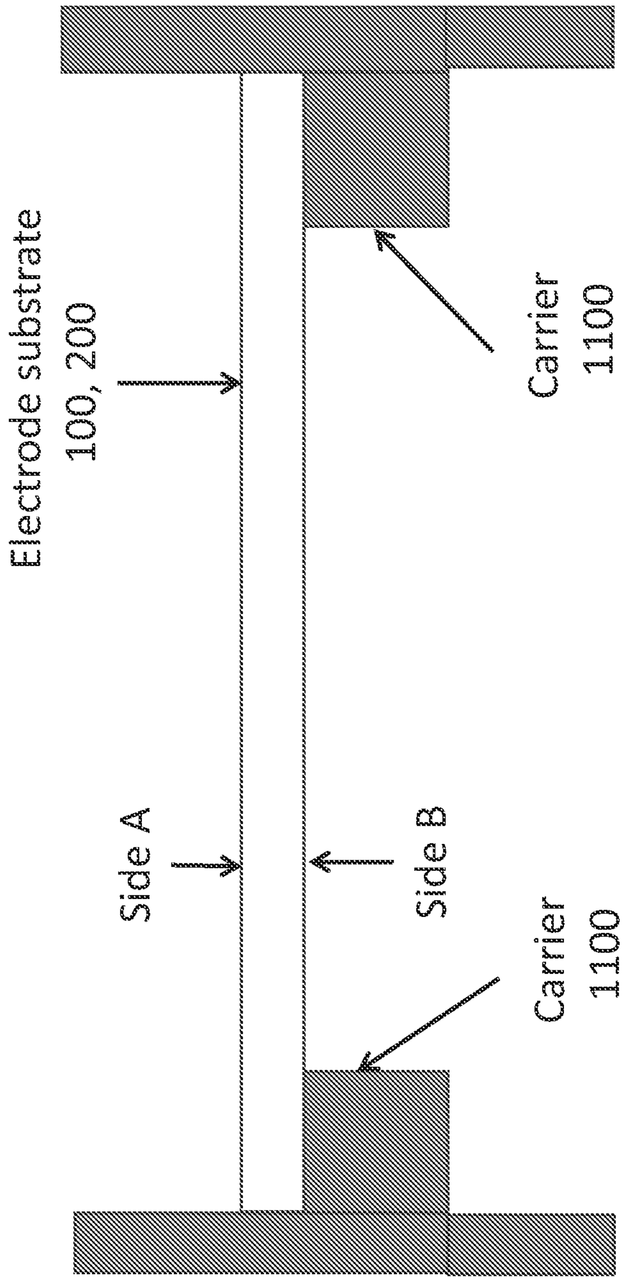


FIG. 10B

FIG. 11


Electrode substrate
100, 200
Carrier
1100
Side A
Side B
Carrier
1100

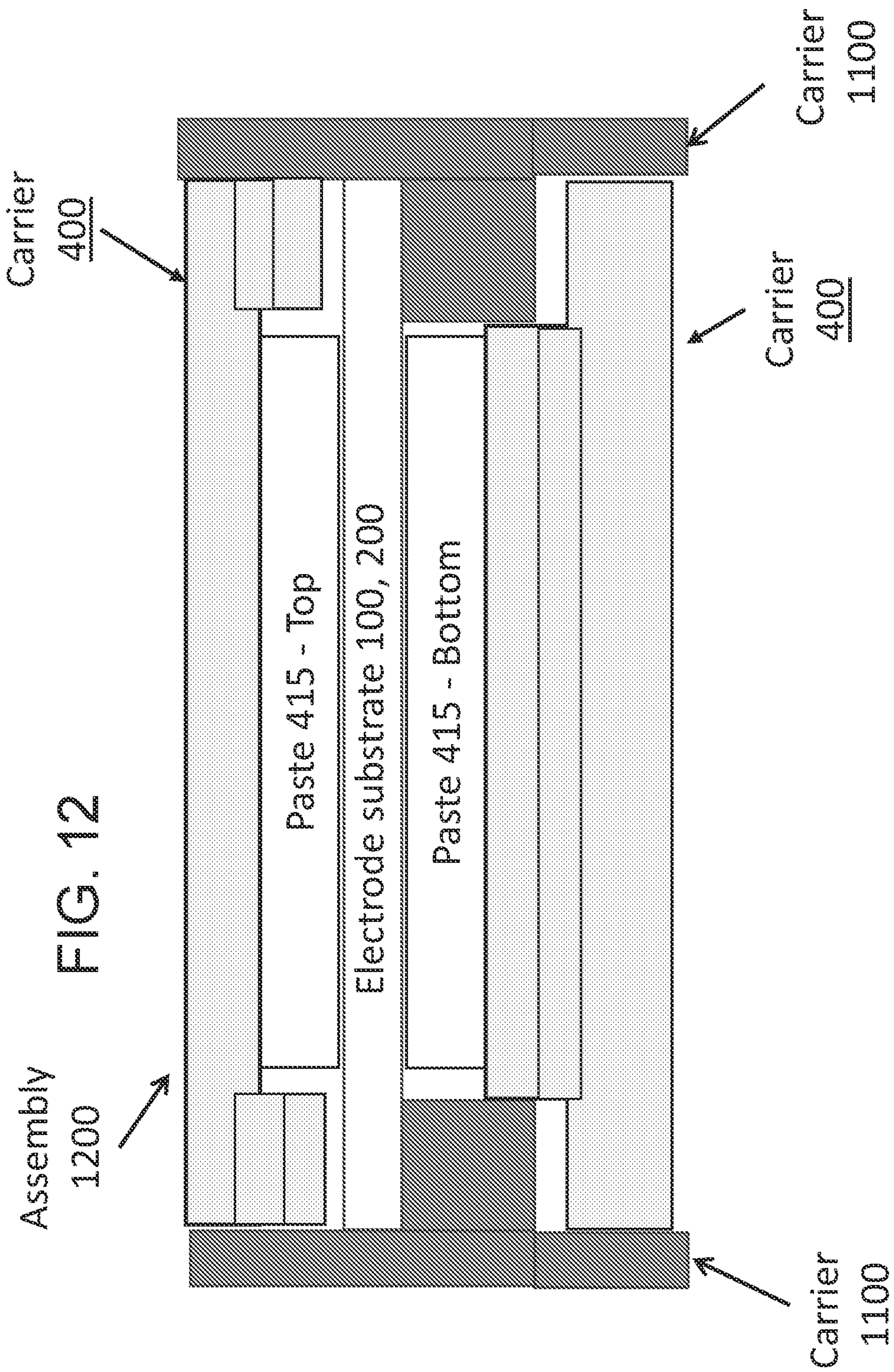
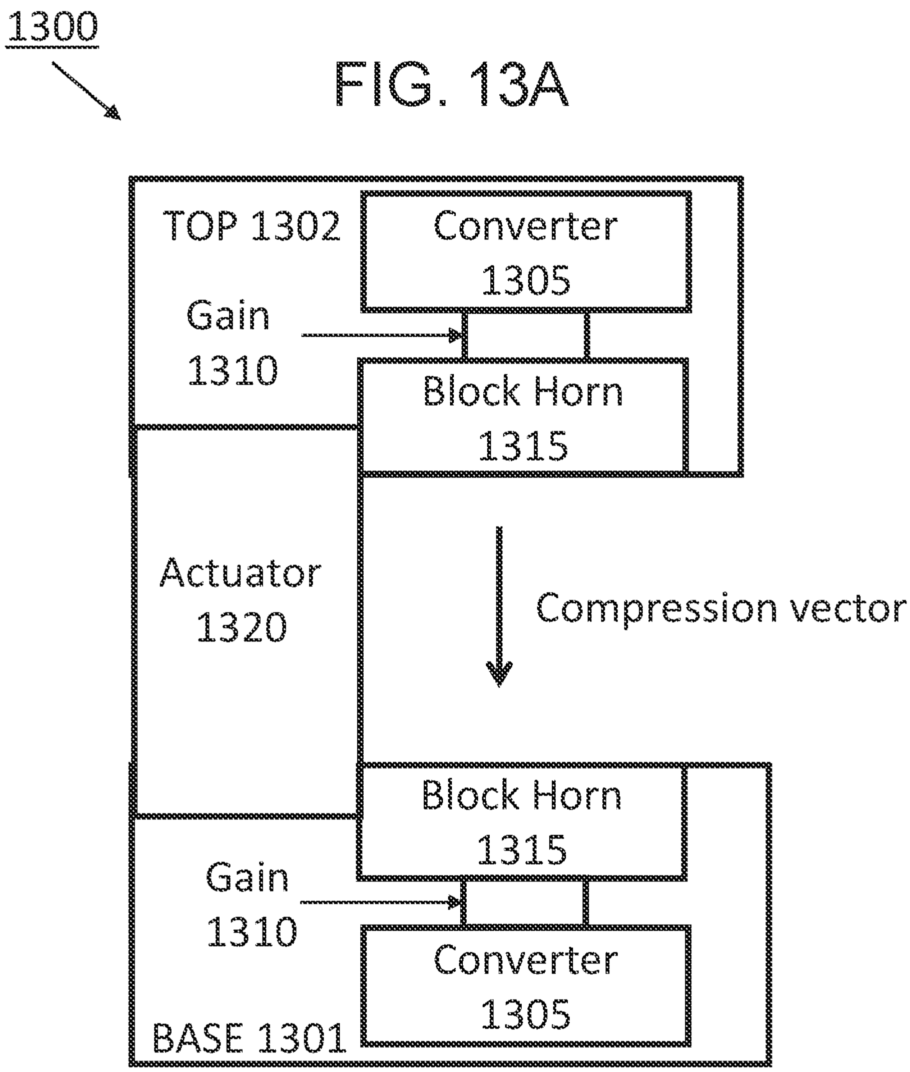

Carrier
1100
Carrier
400
Carrier
400
Paste 415 - Top
Electrode substrate 100, 200
Paste 415 - Bottom
Assembly
1200
Carrier
1100

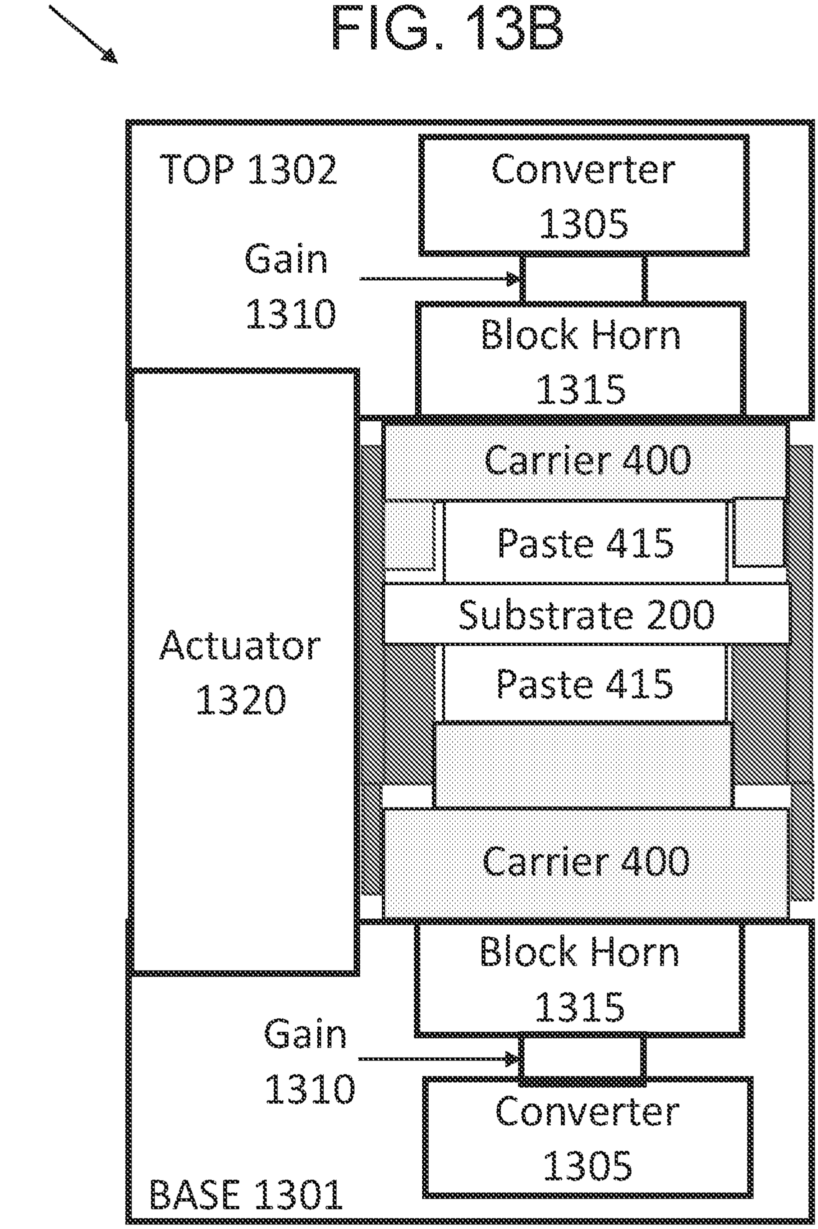
FIG. 12

FIG. 13A


1300
TOP 1302
Converter
1305
Gain
1310
Block Horn
1315
Actuator
1320
Compression vector
Block Horn
1315
Gain
1310
Converter
1305
BASE 1301

1300

FIG. 13B


TOP 1302
Converter 1305
Gain 1310
Block Horn 1315
Carrier 400
Paste 415
Substrate 200
Paste 415
Actuator 1320
Carrier 400
Block Horn 1315
Gain 1310
Converter 1305
BASE 1301

1400

FIG. 14

1500

FIG. 15

1600

FIG. 16

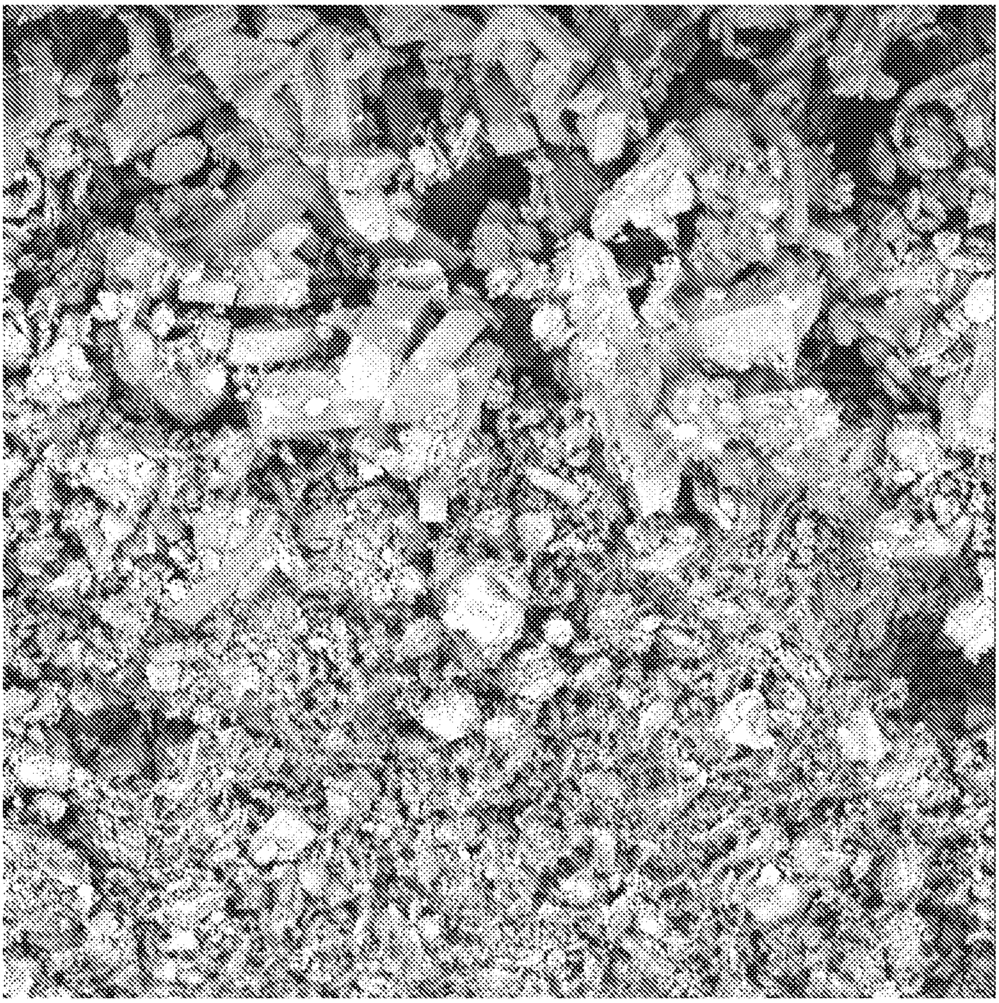
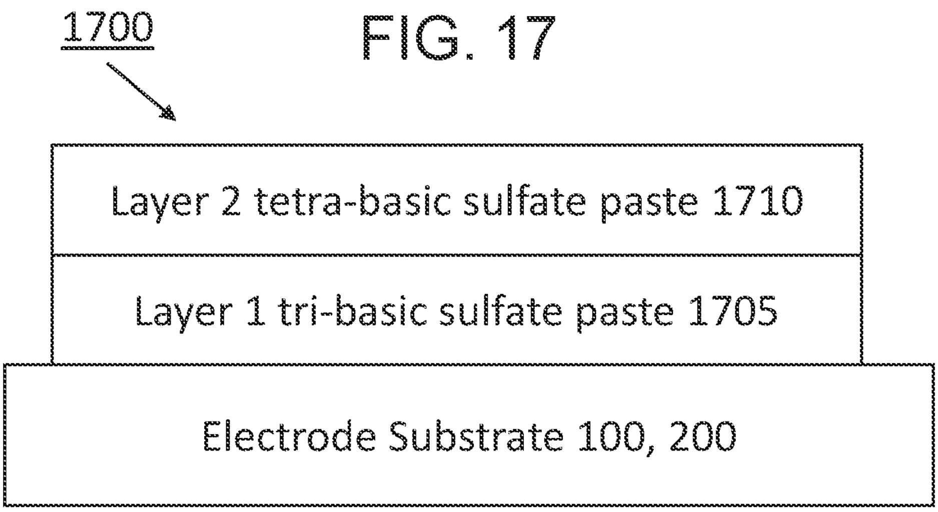


FIG. 17


1700
Layer 2 tetra-basic sulfate paste 1710
Layer 1 tri-basic sulfate paste 1705
Electrode Substrate 100, 200

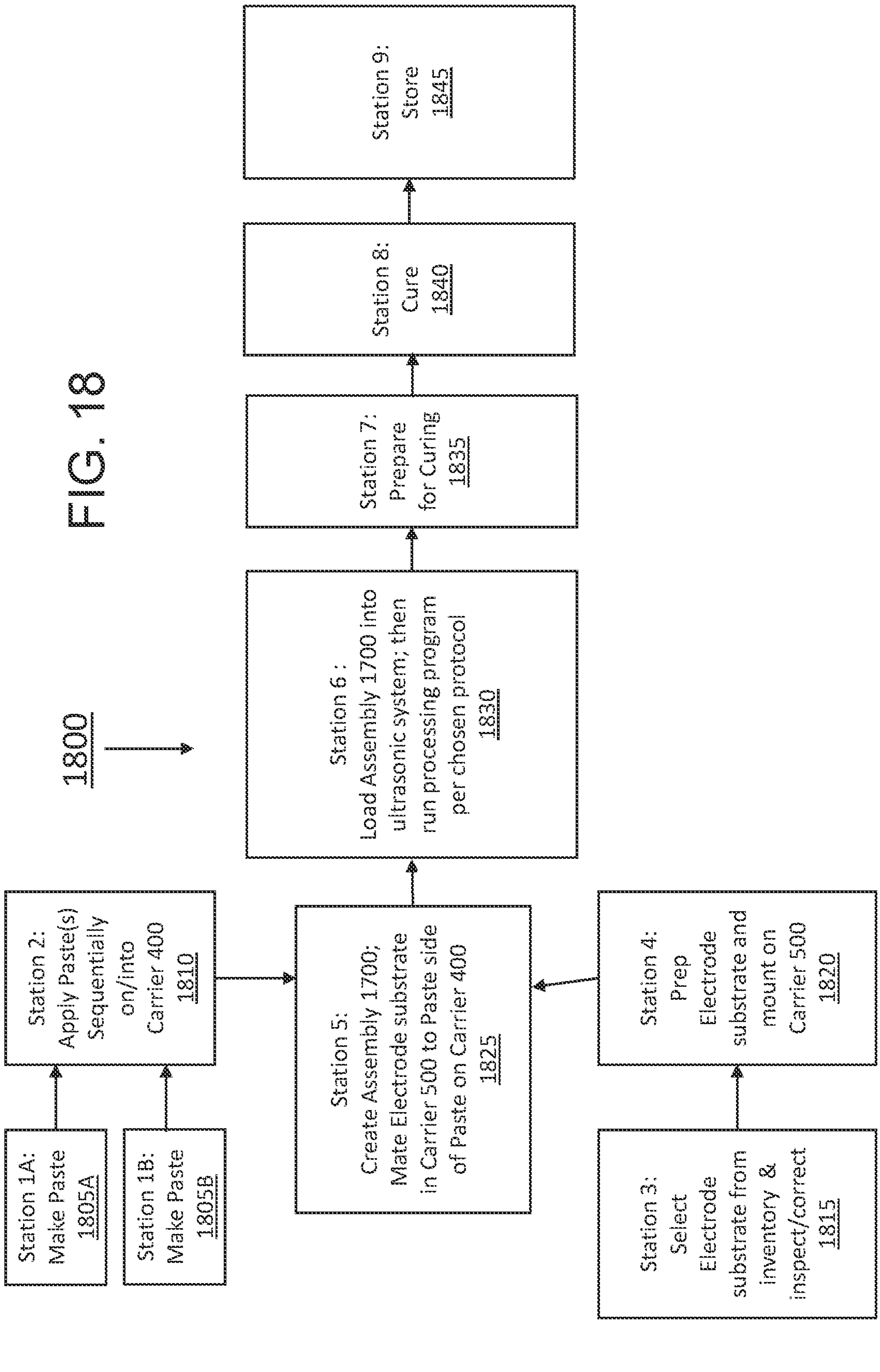

1800
Station 1A: Make Paste 1805A
Station 1B: Make Paste 1805B
Station 2: Apply Paste(s) Sequentially on/into Carrier 400 1810
Station 3: Select Electrode substrate from inventory & inspect/correct 1815
Station 4: Prep Electrode substrate and mount on Carrier 500 1820
Station 5: Create Assembly 1700; Mate Electrode substrate in Carrier 500 to Paste side of Paste on Carrier 400 1825
Station 6 : Load Assembly 1700 into ultrasonic system; then run processing program per chosen protocol 1830
Station 7: Prepare for Curing 1835
Station 8: Cure 1840
Station 9: Store 1845

FIG. 18

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2023/084434

A. CLASSIFICATION OF SUBJECT MATTER

H01M 10/12(2006.01)i; **H01M 10/18**(2006.01)i; **B23K 20/10**(2006.01)i; **H01M 4/16**(2006.01)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)

H01M 10/12(2006.01); B23K 20/10(2006.01); H01M 2/26(2006.01); H01M 4/04(2006.01); H01M 4/66(2006.01)

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

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords: paste, carrier, electrode, press, ultrasonic welding

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2013-073685 A (TOPPAN PRINTING CO., LTD.) 22 April 2013 (2013-04-22) abstract; claim 1; paragraphs [0024], [0031], [0032]; figure 3	1,3
A		2,4
Y	JP 2020-102320 A (SANYO ELECTRIC CO., LTD.) 02 July 2020 (2020-07-02) abstract; claim 1; figure 2	1,3
A	JP 62-103990 A (JAPAN STORAGE BATTERY CO., LTD.) 14 May 1987 (1987-05-14) the entire document	1-4
A	JP 62-274565 A (JAPAN STORAGE BATTERY CO., LTD.) 28 November 1987 (1987-11-28) the entire document	1-4
A	JP 62-098575 A (JAPAN STORAGE BATTERY CO., LTD.) 08 May 1987 (1987-05-08) the entire document	1-4

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

* Special categories of cited documents:
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"D" document cited by the applicant in the international application
"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
22 April 2024	**23 April 2024**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**LEE, Kang Ha**
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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2023/084434

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP 2013-073685 A	22 April 2013	None	
JP 2020-102320 A	02 July 2020	JP 7085976 B2	17 June 2022
JP 62-103990 A	14 May 1987	None	
JP 62-274565 A	28 November 1987	None	
JP 62-098575 A	08 May 1987	None	