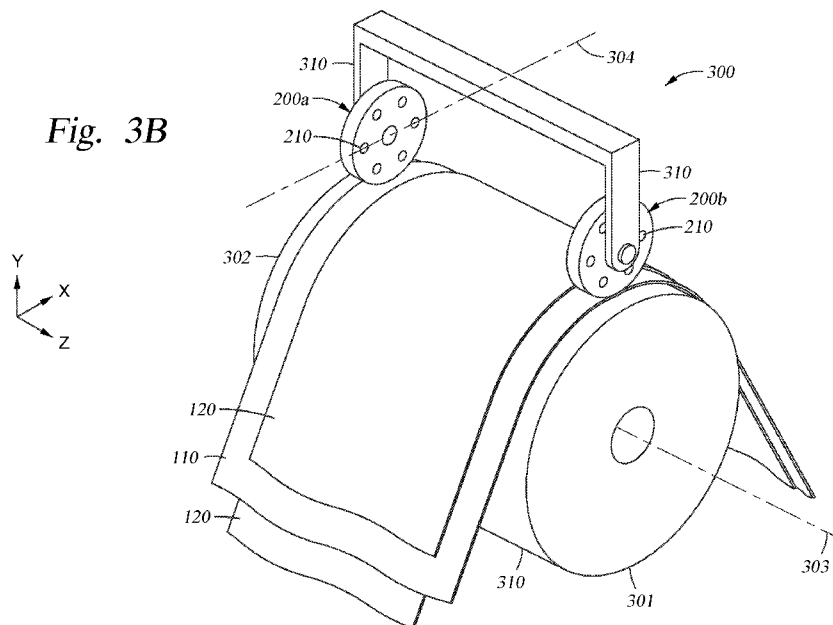




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(57) Abstract: Embodiments of the present disclosure generally relate to flexible substrate fabrication. In particular, embodiments described herein relate to an apparatus and methods for flexible substrate fabrication using nip rollers to improve tension uniformity. In one embodiment, a roller assembly includes a primary roller for transporting a flexible substrate, wherein the primary roller has a first end and a second end, wherein the flexible substrate has a coating disposed hereon, and wherein one or more edge regions are not covered by the coating. The roller assembly further includes a first nip roller disposed at the first end of the primary roller that contacts a first edge region of the one or more edge regions, and a second nip roller disposed at the second end of the primary roller that contacts a second edge region of the one or more edge regions.



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## INCLUSION OF SPECIAL ROLLER TO AVOID CREASING, WRINKLING AND DISTORTION OF FLEXIBLE SUBSTRATE IN ROLL TO ROLL PROCESS

### **BACKGROUND**

#### **Field**

**[0001]** Embodiments of the present disclosure generally relate to flexible substrate fabrication. In particular, embodiments described herein relate to an apparatus and methods for flexible substrate fabrication using nip rollers to improve tension uniformity.

#### **Description of the Related Art**

**[0002]** Flexible substrates may be used for packaging, semiconductor, and photovoltaic applications. Processing of flexible substrates may include coating a flexible substrate with a desired material, such as a metal, semiconductors, and/or dielectric materials. Systems for performing processing of flexible substrates generally include a processing drum, e.g., a cylindrical roller, coupled to a processing system for transporting the substrate, and on which at least a portion of the substrate is processed. Roll-to-roll coating systems thereby provide a relatively high throughput system.

**[0003]** Wrinkling and/or tearing at the edges of the flexible substrate may create issues during double or single side coating, which may further result in irregularities in the final product after coating. Accordingly, what is needed in the art is an apparatus for substrate fabrication, which improves tension uniformity.

### **SUMMARY**

**[0004]** Embodiments of the present disclosure generally relate to flexible substrate fabrication. In particular, embodiments described herein relate to an apparatus and methods for flexible substrate fabrication using nip rollers to improve tension uniformity. In one embodiment, a roller assembly includes a primary roller for transporting a flexible substrate, wherein the primary roller has a first end and a second end, wherein the flexible substrate has a coating disposed hereon, and wherein one or more edge regions are not covered by the coating. The roller assembly further includes a first nip roller disposed at the first end of the primary roller

that contacts a first edge region of the one or more edge regions, and a second nip roller disposed at the second end of the primary roller that contacts a second edge region of the one or more edge regions.

**[0005]** In another embodiment, a process chamber includes a chamber body defining an internal volume therein, and one or more roller assemblies positioned in the internal volume and configured to transport a flexible substrate. Each of the one or more roller assemblies includes a primary roller disposed in the internal volume of the process chamber, a first nip roller having a first plurality of holes formed therethrough, and a second nip roller having a second plurality of holes formed therethrough, wherein each of the first nip roller and the second nip roller contacts a respective edge portion of the flexible substrate.

**[0006]** In yet another embodiment, a process chamber for manufacturing a flexible substrate includes a chamber body defining an internal volume therein, a coating drum, and one or more roller assemblies configured to transport a flexible substrate. Each of the one or more roller assemblies includes a primary roller having a first end and a second end, wherein the primary roller is disposed in the internal volume of the process chamber, a first nip roller is disposed at the first end of the primary roller, wherein the first nip roller has a first plurality of holes formed therethrough, and a second nip roller is disposed at the second end of the primary roller, wherein the second nip roller has a second plurality of holes formed therethrough.

**[0007]** In some embodiments, a non-transitory computer readable medium has stored thereon instructions, which, when executed by a processor, cause the process to perform operations of the above apparatus and/or method.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0008]** 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, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

**[0009]** Figures 1A and 1B are schematic, cross-sectional views of a roller having a flexible substrate disposed thereon according to one or more embodiments.

**[0010]** Figure 2A is a schematic, side-view of a nip roller according to one or more embodiments.

**[0011]** Figure 2B is a schematic, perspective view of the nip roller of Figure 2A according to one or more embodiments.

**[0012]** Figure 3A is a schematic, side-view of a roller assembly according to one or more embodiments.

**[0013]** Figure 3B is a schematic, perspective view of the roller assembly of Figure 3A according to one or more embodiments.

**[0014]** Figure 4 is a schematic, cross-sectional view of a process chamber according to one or more embodiments.

**[0015]** Figure 5 is a method of fabricating a flexible substrate in the process chamber of Figure 4 according to one or more embodiments.

**[0016]** To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

### **DETAILED DESCRIPTION**

**[0017]** Embodiments of the present disclosure generally relate to flexible substrate fabrication. In particular, embodiments described herein relate to an apparatus and methods for flexible substrate fabrication using nip rollers to improve tension uniformity. Certain details are set forth in the following description and in FIGS. 1A to 5 to provide a thorough understanding of various embodiments of the disclosure. Other details describing well-known structures and systems often associated with web coating, web transfer, and adjusting web tension of a flexible substrate or web in a roll-to-roll deposition system are not set forth in the following disclosure to avoid unnecessarily obscuring the description of the various embodiments.

**[0018]** Many of the details, dimensions, angles and other features shown in the Figures are merely illustrative of particular embodiments. Accordingly, other embodiments can have other details, components, dimensions, angles and features without departing from the spirit or scope of the present disclosure. In addition, further embodiments of the disclosure can be practiced without several of the details described below.

**[0019]** Embodiments described herein will be described below in reference to a roll-to-roll coating system, such as TopMet™, SmartWeb™, TopBeam™, all of which are available from Applied Materials, Inc. of Santa Clara, California. Other tools capable of performing roll-to-roll processing can also be adapted to benefit from the embodiments described herein. The apparatus description described herein is illustrative and should not be construed or interpreted as limiting the scope of the embodiments described herein. In addition, the embodiments described herein are applicable to a flexible substrate having a coating on a single side or a flexible substrate having a coating on opposing sides or a “dual-sided” coating.

**[0020]** It is noted that while the particular substrate on which some embodiments described herein can be practiced is not limited, it is particularly beneficial to practice the embodiments on flexible substrates, including for example, web-based substrates, panels and discrete sheets.

**[0021]** It is also noted here that a flexible substrate or web as used within the implementations described herein can typically be characterized in that it is bendable. The term “web” can be synonymously used to the term “strip,” the term “flexible substrate,” or the like. For example, the web as described in implementations herein can be a foil. Synonyms of the term “web” are strip, foil, flexible substrate or the like. Typically, a web includes a continuous sheet of thin and flexible material. Typical web materials are metals, plastics, paper, or the like. A web as understood herein is typically a three dimensional solid body. The thickness of the web as understood herein can be less than 1 mm, more typically less than 500 μm or even less than 10 μm. A web as understood herein can have a width of at least 0.5 m, more typically at least 1 m or even at least 4 m. A web as understood herein can have a length of at least 1 km, 25 km or even 60 km.

**[0022]** It is further noted that in the present disclosure, a “roll” or a “roller” can be understood as a device, which provides a surface, with which a substrate (or a part of a substrate) can be in contact during the presence of the substrate in the processing system. At least a part of the “roll” or “roller” as referred to herein can include a circular-like shape for contacting the substrate to be processed or already processed. In some implementations, the “roll” or “roller” can have a cylindrical or substantially cylindrical shape. The substantially cylindrical shape can be formed about a straight longitudinal axis or can be formed about a bent longitudinal axis. According to some implementations, the “roll” or “roller” as described herein can be adapted for being in contact with a flexible substrate. For example, a “roll” or “roller” as referred to herein can be a guiding roller adapted to guide a substrate while the substrate is processed (such as during a deposition process) or while the substrate is present in a processing system; a spreader roller adapted for providing a defined tension for the substrate to be coated; a deflecting roller for deflecting the substrate according to a defined travelling path; a processing roller for supporting the substrate during processing, such as a process drum, for example, a coating roller or a coating drum; an adjusting roller, a supply roll, a take-up roll or the like. The “roll” or “roller” as described herein can comprise a metal.

**[0023]** Web coating for anode pre-lithiation and solid metal anode formation typically involves thick (three to twenty micron) metallic lithium deposition on single or double-side-coated and calendered alloy-type graphite anodes and current collectors, for example, six micron or thicker copper foil, nickel foil, or metallized plastic web. Variations in tension along the web during processing can lead to wrinkles and other deformities at the edges of the processed web, which can ruin the processed web. One way of adjusting web tension in the chamber is to shut down the web system, open the web system, and physically adjust the tension. However, this can lead to significant downtime to the web system, which increases the cost of ownership. In addition, these deformities in the web may not be detected until after the entire web is processed. This can lead to scrapping the processed web, which increases material costs. Thus, it would be advantageous to be able to dynamically adjust tension at the edges of the web during processing to reduce wrinkling and/or tearing at the edges of the flexible substrate without opening the system.

**[0024]** Figures 1A and 1B are schematic, cross-sectional views of a flexible substrate 110 according to one or more embodiments. In one embodiment, the flexible substrate is formed from metal, for example copper, aluminum, nickel, or steel. A thickness 115 of the flexible substrate 110 can be between about 1 micrometer to about 100 micrometers. The flexible substrate 110 is processed in a process chamber, e.g., the process chamber 400 of Figure 4, which contains a plurality of rollers. The rollers may be idle rollers, tension rollers, spreader rollers, etc. In one embodiment, which can be combined with other embodiments described herein, the flexible substrate 110 is disposed on a primary roller 130, and the primary roller 130 is configured to transport the flexible substrate 110.

**[0025]** A coating 120 is provided on the flexible substrate 110. A thickness 125 of the coating 120 can be between about 1 micrometer to about 100 micrometers. The coating 120 can include multiple layers of material. Examples of materials that can be used for the coating 120 include, but are not limited to, carbon, graphite, silicon, silicon oxide, silicon-containing graphite, lithium, lithium metal foil, a lithium alloy foil (e.g. lithium aluminum alloys, lithium silver alloys, etc.), nickel, copper, silver, tin, indium, gallium, tin, bismuth, niobium, molybdenum, tungsten, chromium, titanium, lithium titanate, silicon, oxides thereof, metal oxides, composites thereof, or combinations thereof. In one example, the coating 120 includes a layer of graphite or silicon-containing graphite with a thin layer of lithium disposed thereon. In one embodiment, as shown in Figure 1A, the coating 120 is disposed on two sides of the flexible substrate 110. In another embodiment, as shown in Figure 1B, the coating 120 is disposed on a single side of the flexible substrate 110. The coating 120 covers a central portion of the flexible substrate 110, resulting in uncoated edge regions 140.

**[0026]** The primary roller 130 transports the flexible substrate 110 through the process chamber by creating tension in the flexible substrate 110. However, the coating 120 is raised relative to the flexible substrate 110 due to the thickness 125 of the coating 120. Thus, the edge regions 140 of the flexible substrate 110 do not contact the primary roller 130, thereby forming a gap between the flexible substrate 110 and the primary roller 130. When the edge regions 140 of the flexible substrate 110 do not contact edge regions 135 of the primary roller 130, the edge regions 140 of the flexible substrate 110 do not experience the tension experienced by the central

portion of the flexible substrate 110 having the coating 120 disposed thereon. Maximum stress due to tension differences along the flexible substrate 110 typically occurs at points A, where the coating 120 ends on the flexible substrate 110. This difference in tension along the flexible substrate 110 may result in wrinkling and/or tearing of the flexible substrate 110.

**[0027]** Figure 2A is a schematic, perspective view of a nip roller 200 according to one or more embodiments. Figure 2B is a schematic, perspective view of the nip roller 200 of Figure 2A according to one or more embodiments. The use of the nip roller 200 in this way reduces the risk of wrinkling and/or tearing of the flexible substrate 110. In one embodiment, which can be combined with other embodiments described herein, two nip rollers 200 are used for each primary roller 130, e.g., a first nip roller 200a and a second nip roller 200b (collectively 200). Each nip roller 200 may be mounted to an interior of a processing chamber, such as the processing chamber shown in Figure 4, through a mounting hole 220. The mounting hole 220 is coupled to a mounting device, for example a mounting bracket 310, as shown in FIG. 3. A width 230 of the nip roller 200 can vary from about 5 mm to about 500 mm, for example, from about 10 mm to about 500 mm. A weight of the nip roller 200 can vary from about 10 grams to about 1000 grams, for example, from about 50 grams to about 1000 grams. In one embodiment, which can be combined with other embodiments described herein, the nip roller 200 is fabricated from polyoxymethylene, otherwise known as Delrin. In another embodiment, which can be combined with other embodiments described herein, the nip roller 200 is fabricated from plastic, steel, aluminum, or copper.

**[0028]** In one embodiment, which can be combined with other embodiments described herein, each nip roller 200 has a plurality of holes 210 disposed therethrough. In one embodiment, which can be combined with other embodiments described herein, six holes 210 are formed through each nip roller 200. In another embodiment, which can be combined with other embodiments described herein, eight holes 210 are formed through each nip roller 200. The plurality of holes 210 may be configured to mount one or more weights (not shown) to increase the contact force between the nip roller 200 and the flexible substrate 110. The plurality of holes 210 are disposed about the nip roller 200 in a manner that evenly distributes the added

weight of the one or more weights. In one embodiment, which can be combined with other embodiments described herein, a weight of the one or more weights is between about 1 gram to about 100 grams.

**[0029]** Figure 3A is a schematic, side-view of a roller assembly 300 according to one or more embodiments. An arrow B illustrates the path of the flexible substrate 110 in reference to the nip rollers 200 and the primary roller 130. Figure 3B is a schematic, perspective view of the roller assembly 300 of Figure 3A. The roller assembly 300 includes one or more nip rollers 200 and the primary roller 130, e.g., the first nip roller 200a, a second nip roller 200b, and the primary roller 130. A first plurality of holes 210a are formed through the first nip roller 200a, and a second plurality of holes 210b are formed through the second nip roller 200b. The flexible substrate 110 is threaded between the nip rollers 200 and the primary roller 130.

**[0030]** The primary roller 130 has a first end 301 and a second end 302. In one embodiment, which can be combined with other embodiments described herein, the first nip roller 200a is disposed at the first end 301 of the primary roller 130, and the second nip roller 200b is disposed at the second end 302 of the primary roller 130. The nip roller 200 is used to bring the uncoated edge regions 140 of the flexible substrate 110 in contact with the edge regions 135 of the primary roller 130.

**[0031]** The nip rollers 200 are linearly actuatable along a primary axis 303 of the primary roller 130. A mounting angle  $\alpha$  of the nip roller 200 is defined as the angle between the mounting bracket 310 and a secondary axis 304 perpendicular to the primary axis 303. The mounting angle  $\alpha$  is adjustable and may be modified by adjusting the mounting bracket 310. Additionally, adjusting the mounting angle  $\alpha$  varies the force exerted upon the flexible substrate 110 by the nip roller 200.

**[0032]** Figure 4 is a schematic, cross-sectional view of an exemplary process chamber 400 according to one or more embodiments. Figure 5 is a method 500 of fabricating a flexible substrate 110 in the process chamber 400 of Figure 4 according to one or more embodiments. The process chamber 400 includes a chamber body 402 defining an internal volume 401 therein. In the internal volume 401, the flexible substrate 110 is coated and transported along various roller assemblies, such as the primary roller 130 and nip roller 200. At operation 501, a roll 440 containing the

uncoated flexible substrate 110 is disposed in the internal volume 401. The flexible substrate 110 is unwound from the roll 440 as indicated by the substrate movement direction shown by arrow C. In some embodiments, the flexible substrate 110 on the roll 440 is uncoated. In other embodiments, the flexible substrate 110 on the roll 440 already has the one or more coatings 120 deposited thereon.

**[0033]** At operation 502, the flexible substrate 110 is transported by the rollers, e.g., the primary rollers 130 and the nip rollers 200, to deposition areas provided at a coating drum 420. During operation, the coating drum 420 rotates such that the flexible substrate 110 moves in the direction of arrow C. According to one embodiment, which can be combined with other embodiments described herein, the flexible substrate 110 is guided via one or more primary rollers 130 from the roll 440 to the coating drum 420, and from the coating drum 420 to a second roll (not shown) where the flexible substrate 110 is wound after processing thereof. One or more nip rollers 200 are paired with each of the primary rollers 130 in order to minimize wrinkling and tearing of the flexible substrate 110 during the deposition process.

**[0034]** In one embodiment, which can be combined with other embodiments described herein, the coating drum 420 is coupled to one or more deposition sources 430, for example four or more deposition sources 430. The deposition sources 430 participate in the coating process of the flexible substrate 110. The one or more deposition sources 430 can include at least one of an electron beam source, CVD sources, PECVD sources, and various PVD sources. Exemplary PVD sources include sputtering sources, electron beam evaporation sources, and thermal evaporation sources. In one example, the deposition source 430 is a lithium (Li) evaporation source. One or more tension rollers 410 may be disposed to along the path C of the flexible substrate 110 in order to manipulate the tension of the flexible substrate 110. At operation 503, the flexible substrate 110 is coated with one or more thin films, i.e., one or more coatings 120 are deposited on the flexible substrate 110 by the deposition sources 430. The deposition by the deposition sources 430 takes place while the flexible substrate 110 is guided on the coating drum 420.

**[0035]** The process chamber 400 can further include a system controller 490 operable to control various aspects of the process chamber 400. The system controller 490 facilitates the control and automation of the process chamber 400 and

can include a central processing unit (CPU), memory, and support circuits (or I/O). Software instructions and data can be coded and stored within the memory for instructing the CPU. The system controller 490 can communicate with one or more of the components of the process chamber 400 via, for example, a system bus. A program (or computer instructions) readable by the system controller 490 determines which tasks are performable on a substrate such as the flexible substrate 110. In some aspects, the program is software readable by the system controller 490, which can include code for monitoring processing conditions, controlling the process chamber 400, and/or controlling application of the nip roller(s) 200. Although a single system controller, the system controller 490 is shown, it should be appreciated that multiple system controllers can be used with the aspects described herein.

**[0036]** In summation, the use of nip rollers in combination with the primary roller minimizes wrinkling and/or tearing of the flexible substrate during processing. Because the roller assembly sandwiches the flexible substrate such that equal amounts of tension are provided along the substrate, overall process uniformity is improved.

### **EMBODIMENTS LISTING**

**[0037]** The present disclosure provides, among others, the following embodiments, each of which can be considered as optionally including any alternate embodiments:

**[0038]** Clause 1. A roller assembly, comprising: a primary roller for transporting a flexible substrate, wherein the primary roller has a first end and a second end, wherein the flexible substrate has a coating disposed hereon and one or more edge regions are not covered by the coating; a first nip roller disposed at the first end of the primary roller that contacts a first edge region of the one or more edge regions; and a second nip roller disposed at the second end of the primary roller that contacts a second edge region of the one or more edge regions.

**[0039]** Clause 2. The roller assembly of Clause 1, wherein the first nip roller and the second nip roller comprise polyoxymethylene.

**[0040]** Clause 3. The roller assembly of Clause 1 or Clause 2, wherein a mounting angle of the first nip roller is adjustable.

**[0041]** Clause 4. The roller assembly of any one of Clauses 1-3, wherein a mounting angle of the second nip roller is adjustable.

**[0042]** Clause 5. The roller assembly of any one of Clauses 1-4, wherein the first nip roller and the second nip roller are mounted in a process chamber with one or more mounting brackets.

**[0043]** Clause 6. The roller assembly of any one of Clauses 1-5, wherein a first plurality of holes are formed in the first nip roller.

**[0044]** Clause 7. The roller assembly of Clause 6, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.

**[0045]** Clause 8. The roller assembly of any one of Clauses 1-7, wherein a second plurality of holes are formed in the second nip roller.

**[0046]** Clause 9. The roller assembly of Clause 8, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.

**[0047]** Clause 10. A process chamber, comprising: a chamber body defining an internal volume therein; and one or more roller assemblies positioned in the internal volume and configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises: a primary roller disposed in the internal volume of the process chamber; a first nip roller having a first plurality of holes formed therethrough; and a second nip roller having a second plurality of holes formed therethrough, wherein each of the first nip roller and the second nip roller contacts a respective edge portion of the flexible substrate.

**[0048]** Clause 11. The process chamber of Clause 10, wherein the first nip roller and the second nip roller comprise polyoxymethylene.

**[0049]** Clause 12. The process chamber of Clause 10 or clause 11, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.

**[0050]** Clause 13. The process chamber of any one of Clauses 10-12, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.

**[0051]** Clause 14. The process chamber of any one of Clauses 10-13, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.

**[0052]** Clause 15. A process chamber for manufacturing a flexible substrate, comprising: a chamber body defining an internal volume therein; a coating drum; and one or more roller assemblies configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises: a primary roller having a first end and a second end, wherein the primary roller is disposed in the internal volume of the process chamber; a first nip roller disposed at the first end of the primary roller, wherein the first nip roller has a first plurality of holes formed therethrough; and a second nip roller disposed at the second end of the primary roller, wherein the second nip roller has a second plurality of holes formed therethrough.

**[0053]** Clause 16. The process chamber of Clause 15, wherein the first nip roller and the second nip roller are linearly actuatable along a primary axis of the primary roller.

**[0054]** Clause 17. The process chamber of Clause 15 or Clause 16, wherein the first nip roller and the second nip roller comprise polyoxymethylene.

**[0055]** Clause 18. The process chamber of any one of Clauses 15-17, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.

**[0056]** Clause 19. The process chamber of any one of Clauses 15-18, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.

**[0057]** Clause 20. The process chamber of any one of Clauses 15-19, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.

**[0058]** Embodiments and all of the functional operations described in this specification can be implemented in digital electronic circuitry, or in computer software, firmware, or hardware, including the structural means disclosed in this specification and structural equivalents thereof, or in combinations of them. Embodiments described herein can be implemented as one or more non-transitory computer program products, i.e., one or more computer programs tangibly embodied in a machine readable storage device, for execution by, or to control the operation of, data processing apparatus, e.g., a programmable processor, a computer, or multiple processors or computers.

**[0059]** The processes and logic flows described in this specification can be performed by one or more programmable processors executing one or more computer programs to perform functions by operating on input data and generating output. The processes and logic flows can also be performed by, and apparatus can also be implemented as, special purpose logic circuitry, e.g., an FPGA (field programmable gate array) or an ASIC (application specific integrated circuit).

**[0060]** The term “data processing apparatus” encompasses all apparatus, devices, and machines for processing data, including by way of example a programmable processor, a computer, or multiple processors or computers. The apparatus can include, in addition to hardware, code that creates an execution environment for the computer program in question, e.g., code that constitutes processor firmware, a protocol stack, a database management system, an operating system, or a combination of one or more of them. Processors suitable for the execution of a computer program include, by way of example, both general and special purpose microprocessors, and any one or more processors of any kind of digital computer.

**[0061]** Computer readable media suitable for storing computer program instructions and data include all forms of nonvolatile memory, media and memory devices, including by way of example semiconductor memory devices, e.g., EPROM, EEPROM, and flash memory devices; magnetic disks, e.g., internal hard disks or

removable disks; magneto optical disks; and CD ROM and DVD-ROM disks. The processor and the memory can be supplemented by, or incorporated in, special purpose logic circuitry.

**[0062]** When introducing elements of the present disclosure or exemplary aspects or implementation(s) thereof, the articles “a,” “an,” “the” and “said” are intended to mean that there are one or more of the elements.

**[0063]** The terms “comprising,” “including” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

**[0064]** While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A roller assembly, comprising:
  - a primary roller for transporting a flexible substrate, wherein the primary roller has a first end and a second end, wherein the flexible substrate has a coating disposed hereon and one or more edge regions are not covered by the coating;
  - a first nip roller disposed at the first end of the primary roller that contacts a first edge region of the one or more edge regions; and
  - a second nip roller disposed at the second end of the primary roller that contacts a second edge region of the one or more edge regions.
2. The roller assembly of claim 1, wherein the first nip roller and the second nip roller comprise polyoxymethylene.
3. The roller assembly of claim 1, wherein a mounting angle of the first nip roller is adjustable.
4. The roller assembly of claim 1, wherein a mounting angle of the second nip roller is adjustable.
5. The roller assembly of claim 1, wherein the first nip roller and the second nip roller are mounted in a process chamber with one or more mounting brackets.
6. The roller assembly of claim 1, wherein a first plurality of holes are formed in the first nip roller.
7. The roller assembly of claim 6, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.
8. The roller assembly of claim 1, wherein a second plurality of holes are formed in the second nip roller.

9. The roller assembly of claim 8, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.
10. A process chamber, comprising:  
a chamber body defining an internal volume therein; and  
one or more roller assemblies positioned in the internal volume and configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises:  
a primary roller disposed in the internal volume of the process chamber;  
a first nip roller having a first plurality of holes formed therethrough; and  
a second nip roller having a second plurality of holes formed therethrough, wherein each of the first nip roller and the second nip roller contacts a respective edge portion of the flexible substrate.
11. The process chamber of claim 10, wherein the first nip roller and the second nip roller comprise polyoxymethylene.
12. The process chamber of claim 10, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.
13. The process chamber of claim 10, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.
14. The process chamber of claim 10, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.
15. A process chamber for manufacturing a flexible substrate, comprising:  
a chamber body defining an internal volume therein;  
a coating drum; and

one or more roller assemblies configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises:

a primary roller having a first end and a second end, wherein the primary roller is disposed in the internal volume of the process chamber;

a first nip roller disposed at the first end of the primary roller, wherein the first nip roller has a first plurality of holes formed therethrough; and

a second nip roller disposed at the second end of the primary roller, wherein the second nip roller has a second plurality of holes formed therethrough.

16. The process chamber of claim 15, wherein the first nip roller and the second nip roller are linearly actuatable along a primary axis of the primary roller.

17. The process chamber of claim 15, wherein the first nip roller and the second nip roller comprise polyoxymethylene.

18. The process chamber of claim 15, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.

19. The process chamber of claim 15, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.

20. The process chamber of claim 15, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.

**AMENDED CLAIMS****received by the International Bureau on 21 September 2022 (21.09.2022)**

- [Claim 1] A roller assembly, comprising:  
a primary roller for transporting a flexible substrate, wherein the primary roller has a first end and a second end, wherein the flexible substrate has a coating disposed thereon and one or more edge regions are not covered by the coating;  
a first nip roller disposed at the first end of the primary roller that contacts a first edge region of the one or more edge regions, a mounting angle of the first nip roller being adjustable; and  
a second nip roller disposed at the second end of the primary roller that contacts a second edge region of the one or more edge regions.
- [Claim 2] The roller assembly of claim 1, wherein the first nip roller and the second nip roller comprise polyoxymethylene.
- [Claim 3] The roller assembly of claim 1, wherein the first nip roller is linearly actuatable along a primary axis of the primary roller.
- [Claim 4] The roller assembly of claim 1, wherein a mounting angle of the second nip roller is adjustable.
- [Claim 5] The roller assembly of claim 1, wherein the first nip roller and the second nip roller are mounted in a process chamber with one or more mounting brackets.
- [Claim 6] The roller assembly of claim 1, wherein a first plurality of holes are formed in the first nip roller.
- [Claim 7] The roller assembly of claim 6, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.
- [Claim 8] The roller assembly of claim 1, wherein a second plurality of holes are formed in the second nip roller.
- [Claim 9] The roller assembly of claim 8, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.
- [Claim 10] A process chamber, comprising:  
a chamber body defining an internal volume therein; and  
one or more roller assemblies positioned in the internal volume and configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises:  
a primary roller disposed in the internal volume of the process chamber;

- a first nip roller having a first plurality of holes formed therethrough;  
and  
a second nip roller having a second plurality of holes formed therethrough, wherein each of the first nip roller and the second nip roller contacts a respective edge portion of the flexible substrate.
- [Claim 11] The process chamber of claim 10, wherein the first nip roller and the second nip roller comprise polyoxymethylene.
- [Claim 12] The process chamber of claim 10, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.
- [Claim 13] The process chamber of claim 10, further comprising one or more weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.
- [Claim 14] The process chamber of claim 10, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.
- [Claim 15] A process chamber for manufacturing a flexible substrate, comprising:  
a chamber body defining an internal volume therein;  
a coating drum; and  
one or more roller assemblies configured to transport a flexible substrate, wherein each of the one or more roller assemblies comprises:  
a primary roller having a first end and a second end, wherein the primary roller is disposed in the internal volume of the process chamber;  
a first nip roller disposed at the first end of the primary roller, wherein the first nip roller has a first plurality of holes formed therethrough; and  
a second nip roller disposed at the second end of the primary roller, wherein the second nip roller has a second plurality of holes formed therethrough.
- [Claim 16] The process chamber of claim 15, wherein the first nip roller and the second nip roller are linearly actuatable along a primary axis of the primary roller.
- [Claim 17] The process chamber of claim 15, wherein the first nip roller and the second nip roller comprise polyoxymethylene.
- [Claim 18] The process chamber of claim 15, further comprising one or more weights mounted to the first plurality of holes in order to increase the weight of the first nip roller.
- [Claim 19] The process chamber of claim 15, further comprising one or more

weights mounted to the second plurality of holes in order to increase the weight of the second nip roller.

[Claim 20]

The process chamber of claim 15, wherein the first nip roller and the second nip roller are mounted to the chamber body with one or more mounting brackets.



Fig. 1A



Fig. 1B

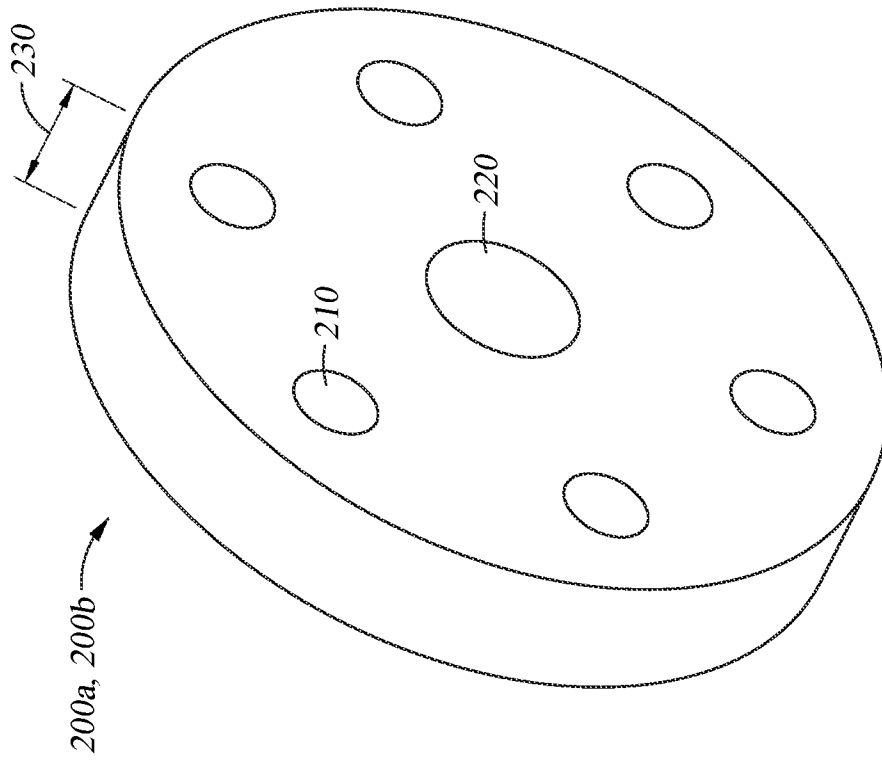


Fig. 2B

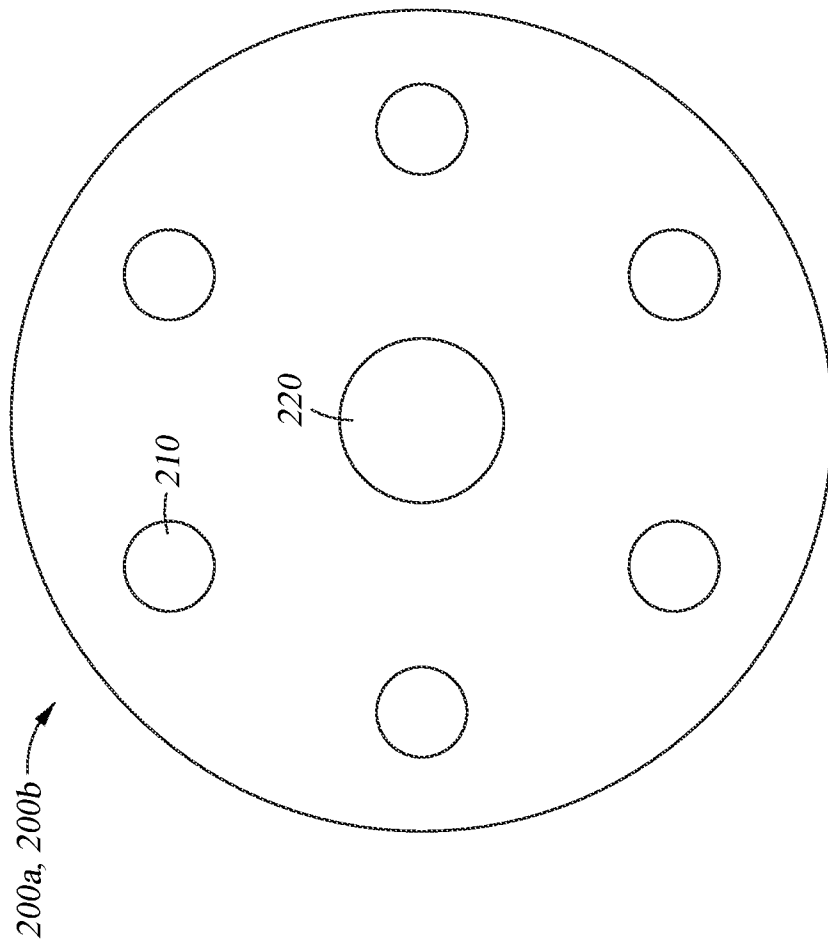
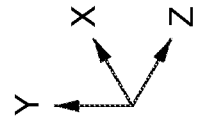
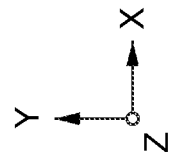


Fig. 2A



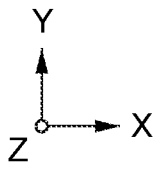
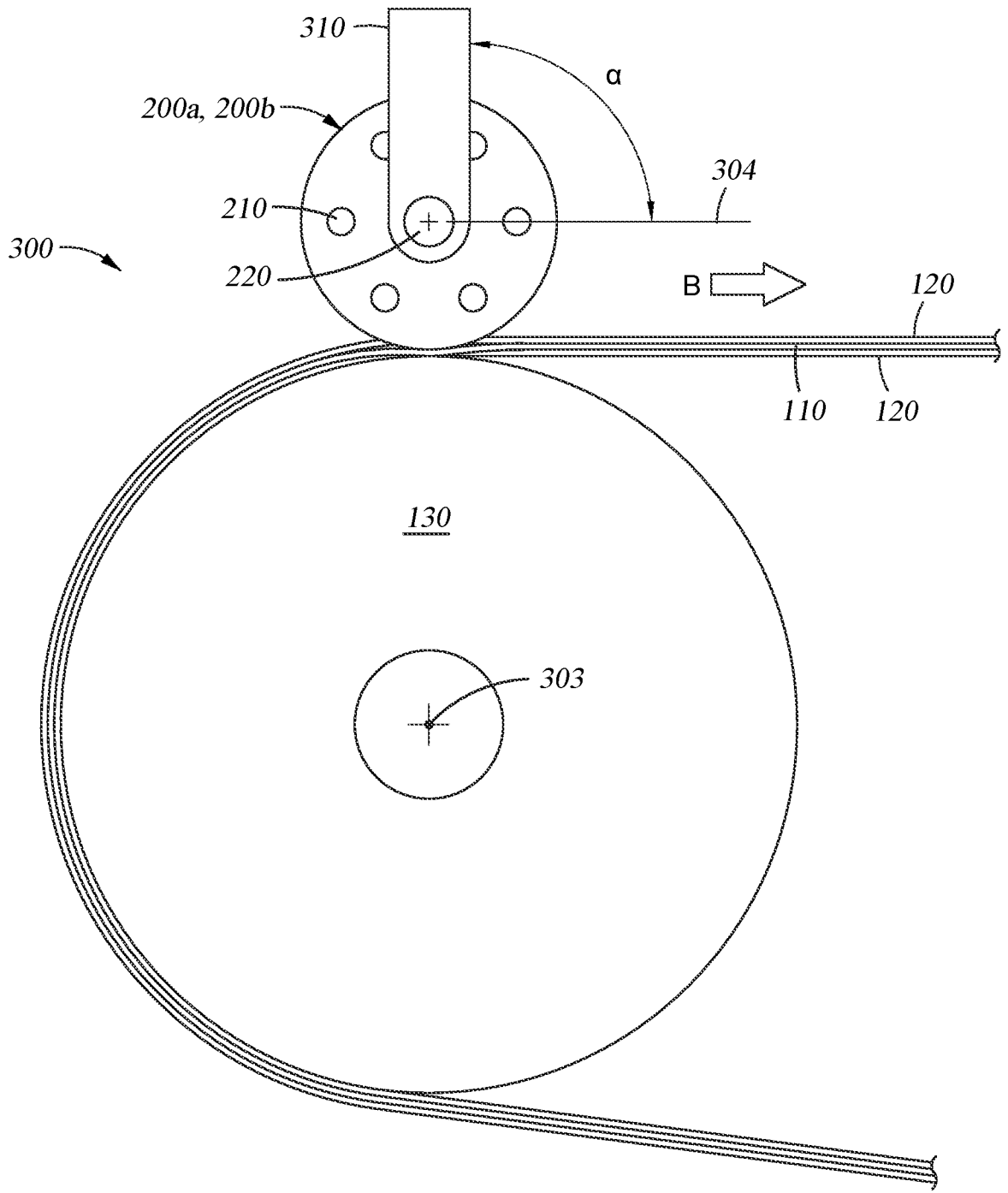


Fig. 3A

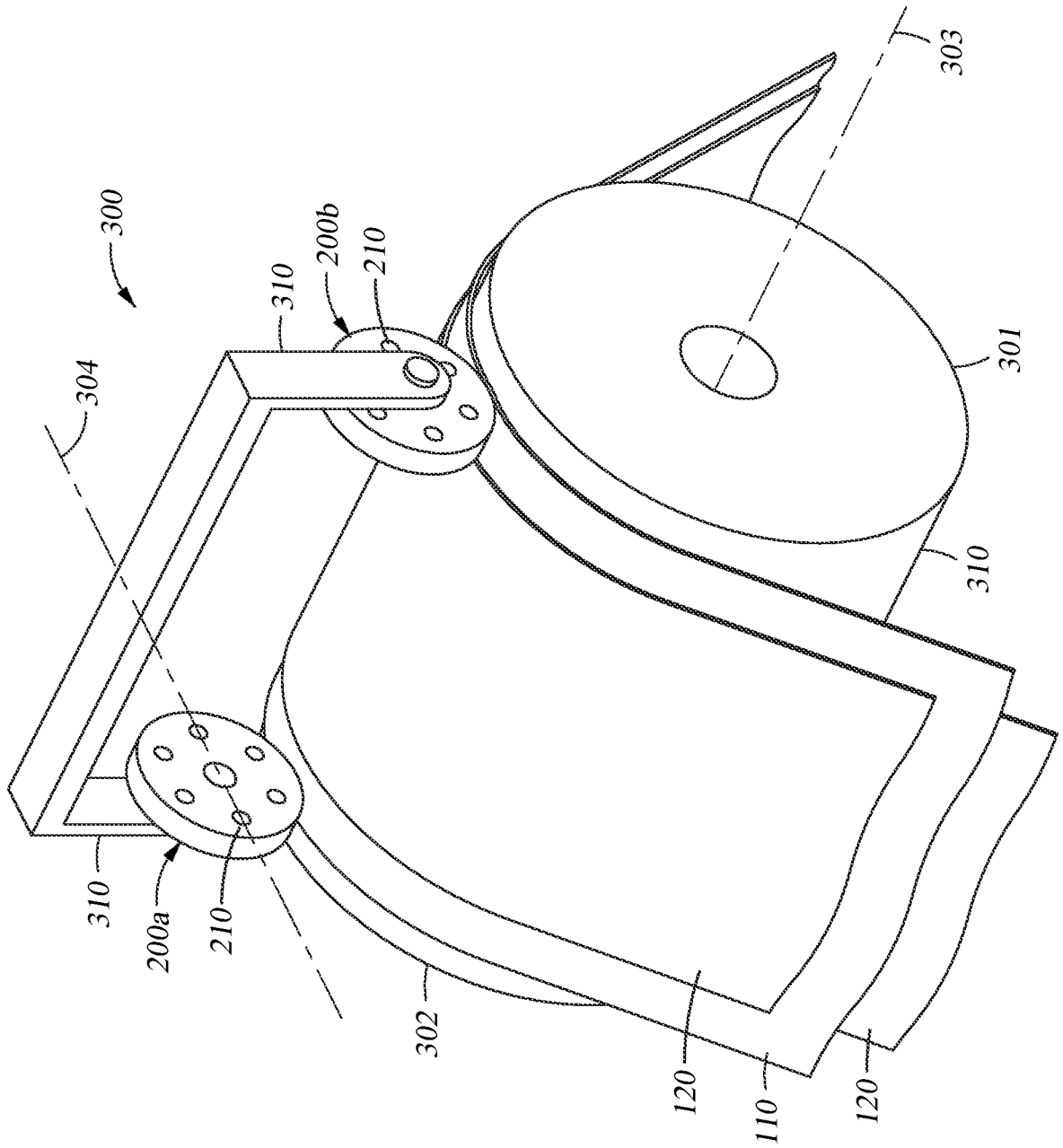
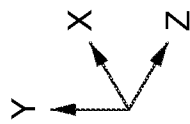
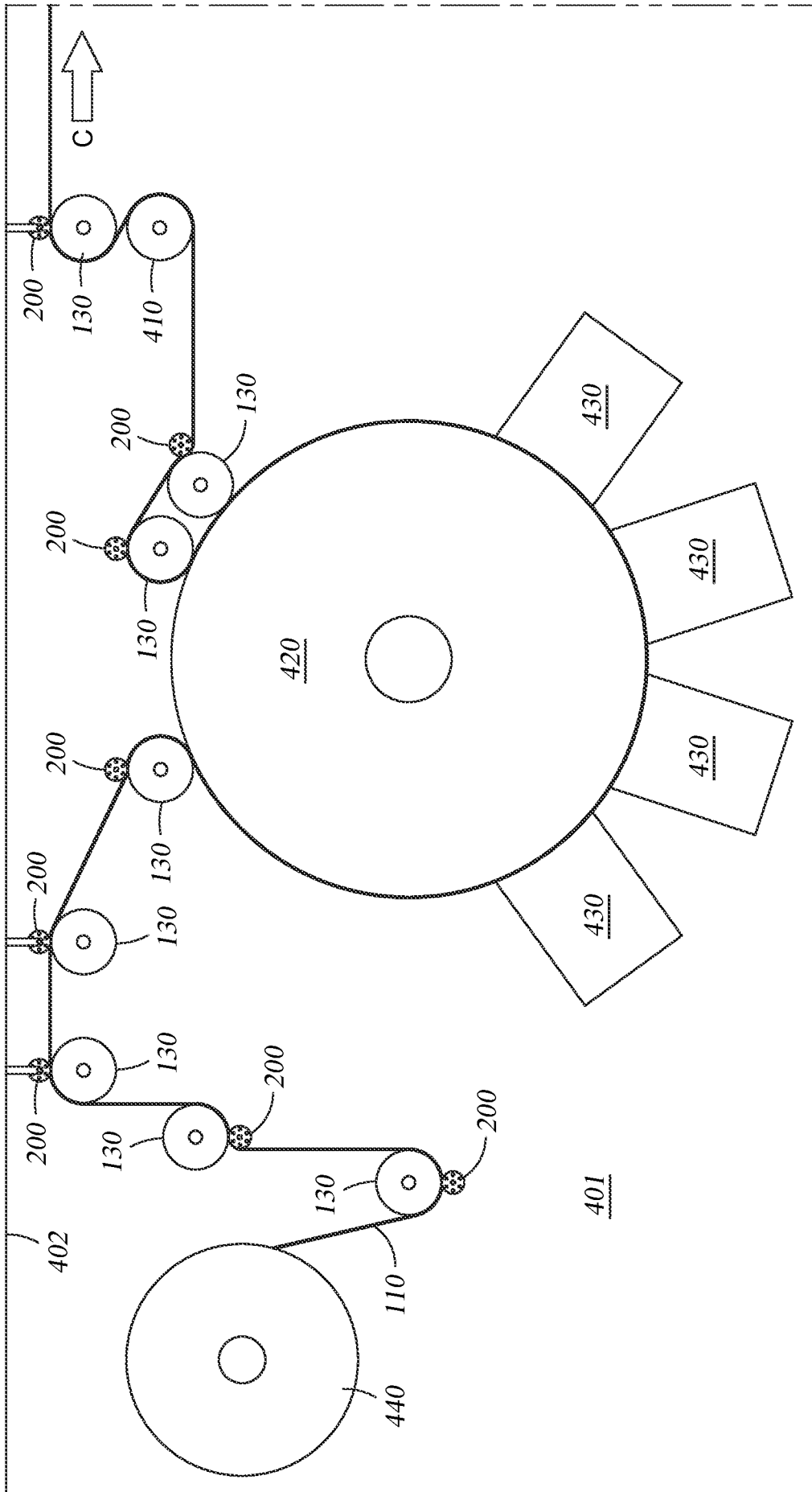


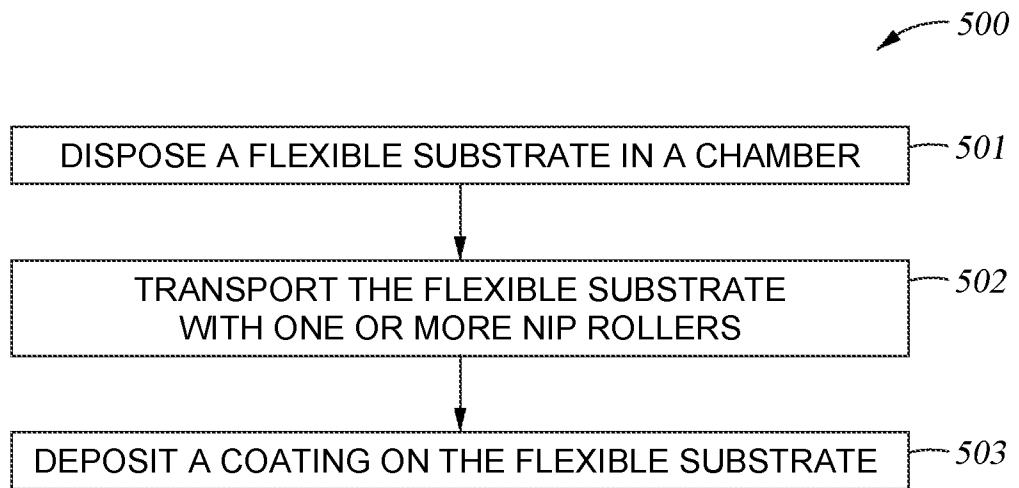
Fig. 3B





400

Fig. 4



*Fig. 5*

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2022/026655

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> C23C 14/56(2006.01)i; C23C 14/50(2006.01)i; C23C 16/54(2006.01)i  According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) C23C 14/56(2006.01); B05D 7/04(2006.01); B32B 37/00(2006.01); C23C 16/458(2006.01); C23C 16/54(2006.01); H01L 21/205(2006.01); H01L 21/677(2006.01); H01L 31/04(2006.01); H01L 31/0445(2014.01); H01L 31/18(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: roll, wrinkling, flexible, substrate, web, edge, coating, hole, weight		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 2011-038162 A (FUJI ELECTRIC HOLDINGS CO., LTD.) 24 February 2011 (2011-02-24) paragraphs [0013], [0015], [0023]-[0024], [0026], [0028] and figures 1, 3	1-20
A	KR 10-2013-0097222 A (NITTO DENKO CORPORATION) 02 September 2013 (2013-09-02) paragraph [0051] and figure 1	1-20
A	US 2016-0190383 A1 (BEIJING APOLLO DING RONG SOLAR TECHNOLOGY CO., LTD.) 30 June 2016 (2016-06-30) paragraph [0033] and figure 7	1-20
A	JP 2011-032555 A (FUJI ELECTRIC HOLDINGS CO., LTD.) 17 February 2011 (2011-02-17) paragraph [0039] and figure 4	1-20
A	KR 10-1307096 B1 (YAS CO., LTD.) 11 September 2013 (2013-09-11) claim 2 and figures 4-5	1-20
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> 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 "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 <b>08 August 2022</b>		Date of mailing of the international search report <b>08 August 2022</b>
Name and mailing address of the ISA/KR <b>Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon 35208, Republic of Korea</b> Facsimile No. +82-42-481-8578		Authorized officer <b>PARK, Tae Wook</b> Telephone No. +82-42-481-5560

**INTERNATIONAL SEARCH REPORT**  
**Information on patent family members**

International application No. <b>PCT/US2022/026655</b>
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		JP 2013-122500 A	20 June 2013
		TW 201334878 A	01 September 2013
		US 2014-0065304 A1	06 March 2014
		WO 2013-084959 A1	13 June 2013
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JP 2011-032555 A	17 February 2011	None	
KR 10-1307096 B1	11 September 2013	None	