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(54) **Title:** ARTICLE TRANSPORT VEHICLE

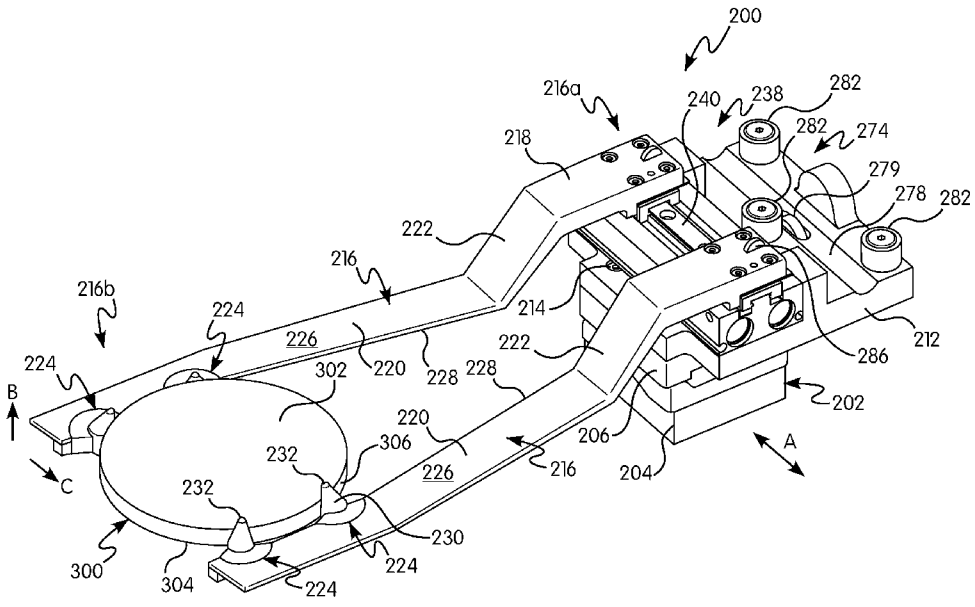

FIG. 3

(57) Abstract: An article transport vehicle (200) has: a carrier base (202) configured for movement along a guideway and a pair of gripping arms (216), each gripping arm (216) having a first end (216a) connected to the carrier base (202) and a second end (216b) protruding from the carrier base (202). The pair of gripping arms (216) is movable between a closed position configured for holding an article (302) and an open position configured for releasing the article (302). The article transport vehicle (200) further has a closure mechanism (238) for moving the pair of gripping arms (216) between the closed position and the open position. The closure mechanism (238) is configured for biasing the pair of gripping arms (216) to the closed position and moving the pair of gripping arms (216) to the open position when the carrier base (202) is positioned at a predetermined portion of the guideway.

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[Continued on next page]

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ARTICLE TRANSPORT VEHICLE

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to an article transport vehicle. In particular, the present invention relates to an optical article transport vehicle movable along a guideway, the optical article transport vehicle having a pair of gripping arms for gripping an optical article and movable between an open position and a closed position, wherein the pair of gripping arms are movable to the open position when the optical article transport base is positioned at a predetermined portion of the guideway.

Description of the Related Art

[0002] With optical articles, such as lenses, one or more surfaces may be subjected to a treatment to enhance the overall performance and function of the optical articles. Examples of such treatments include the formation of one or more coatings on a surface of an optical substrate of the optical article.

[0003] In order to manufacture a coated optical article from an uncoated optical substrate, a variety of manufacturing techniques have been developed. For smaller batches, it may be economical to manufacture coated optical articles by passing a single optical article through a plurality of discrete processing stations, such as a washing station, a coating station, and a curing station, before a subsequent optical article is processed. In large scale operations, optical articles may be processed on an automated production line configured for processing hundreds of optical articles per hour. For example, optical articles maybe continuously loaded onto a moving conveyor belt which passes through a plurality of processing stations. With certain processing stations, such as a spin coating station, optical articles must be removed from the conveyor belt and placed in the processing station. For such operations, special equipment must be provided to move the optical articles from the conveyor belt to the processing stations. During handling of the optical article, special care must be taken to prevent contact between the processing equipment and a coating surface of the optical article.

[0004] It would be desirable to develop a new optical article transport system for moving optical articles along the production line. In particular, it would be desirable to develop a new optical article transport vehicle for use in a production line having a plurality of processing stations.

SUMMARY OF THE INVENTION

[0005] In accordance with the present invention, there may be provided an article transport vehicle with a carrier base configured for movement along a guideway. The article transport vehicle may further have a pair of gripping arms, each gripping arm having a first end connected to the carrier base and a second end protruding from the carrier base. The pair of gripping arms may be movable between a closed position configured for holding an article and an open position configured for releasing the article. The article transport vehicle may further have a closure mechanism for moving the pair of gripping arms between the closed position and the open position. The closure mechanism may be configured for biasing the pair of gripping arms to the closed position and moving the pair of gripping arms to the open position when the carrier base is positioned at a predetermined portion of the guideway.

[0006] In accordance with the present invention, the closure mechanism may have a pneumatic reservoir having a first chamber and a second chamber in fluid communication with the first chamber. The closure mechanism may have an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator. The first chamber may have a first volume and the second chamber may have a second volume, wherein the second volume may be smaller than the first volume. In the closed position, a pressure in the first chamber may be higher than a pressure in the second chamber such that the actuator is positioned in a first position, and wherein, in the open positon, the pressure in the first chamber may be lower than the pressure in the second chamber such that the actuator is positioned in a second position. The closure mechanism may have a linkage arrangement movable between a first position, wherein the pair of gripping arms is in the closed position, and a second positon, wherein the pair of gripping arms is in the open position. The linkage arrangement may be biased to the first position by at least one biasing device, such as a spring. The second end of each gripping arm may have a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm. At least one of the pair of gripping arms may be made from a first material and at least one of the projections is made from a second material different from the first material.

[0007] In accordance with the present invention, a secondary closure mechanism may be provided to bias the pair of gripping arms to the closed position. For example, the secondary closure mechanism may be a spring or a resiliently elastic band. At least one arm position indicator may be provided on at least one of the pair of gripping arms. The at least one arm

position indicator may be configured for indicating a position of the at least one of the pair of gripping arms. For example, the at least one arm position indicator may be a permanent magnet. At least one centering element may be for engaging an alignment rail along at least a portion of the guideway for centering the carrier base relative to the guideway. The pair of gripping arms may protrude relative to the carrier base in a direction substantially perpendicular to a direction of travel of the carrier base. The carrier base may have a magnetic flux source.

[000S] The features that characterize the present invention are pointed out with particularity in the claims, which are annexed to and form a part of this disclosure. These and other features of the invention, its operating advantages, and the specific objects obtained by its use will be more fully understood from the following detailed description in which non-limiting examples of the invention are illustrated and described.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a schematic representation of an optical article production line in accordance with some examples of the present invention;

[0010] FIG. 2 is a representative perspective view of a portion of a guideway for use with the optical article production line according to some examples of the present invention;

[0011] FIG. 3 is a representative perspective view of an optical article transport vehicle for use with an optical article production line according to some examples of the present invention;

[0012] FIG. 4 is a representative side view of the optical article transport vehicle shown in FIG. 3;

[0013] FIG. 5 is a representative top view of the optical article transport vehicle shown in FIG. 3 with a pair of gripping arms shown in an open position;

[0014] FIG. 6 is a representative top view of the optical article transport vehicle shown in FIG. 3 with the pair of gripping arms shown in a closed position;

[0015] FIG. 7 is a representative schematic view of a pneumatic system of the optical article transport vehicle according to some examples of the present invention;

[0016] FIG. 8 is a representative perspective view of an optical article transport vehicle shown on a portion of a guideway;

[0017] **FIG. 9** is a representative side view of the optical article transport vehicle shown in **FIG. 8**;

[0018] **FIG. 10** is a representative top view of an optical article transport vehicle according to some examples of the present invention with a pair of gripping arms shown in an open position; and

[0019] **FIG. 11** is a representative top view of the optical article transport vehicle shown in **FIG. 10** with the pair of gripping arms shown in a closed position.

[0020] In **FIGS. 1-11,** like characters refer to the same components and elements, as the case may be, unless otherwise stated.

DETAILED DESCRIPTION OF THE INVENTION

[0021] As used herein, the singular form of "a", "an", and "the" include plural referents unless the context clearly dictates otherwise.

[0022] Spatial or directional terms, such as "left", "right", "inner", "outer", "above", "below", and the like, relate to the invention as shown in the drawing figures and are not to be considered as limiting as the invention can assume various alternative orientations.

[0023] All numbers and ranges used in the specification and claims are to be understood as being modified in all instances by the term "about". By "about" is meant plus or minus twenty-five percent of the stated value, such as plus or minus ten percent of the stated value. However, this should not be considered as limiting to any analysis of the values under the doctrine of equivalents.

[0024] Unless otherwise indicated, all ranges or ratios disclosed herein are to be understood to encompass the beginning and ending values and any and all subranges or subratios subsumed therein. For example, a stated range or ratio of "1 to 10" should be considered to include any and all subranges or subratios between (and inclusive of) the minimum value of 1 and the maximum value of 10; that is, all subranges or subratios beginning with a minimum value of 1 or more and ending with a maximum value of 10 or less. The ranges and/or ratios disclosed herein represent the average values over the specified range and/or ratio.

[0025] The terms "first", "second", and the like are not intended to refer to any particular order or chronology, but refer to different conditions, properties, or elements.

[0026] All documents referred to herein are "incorporated by reference" in their entirety.

[0027] The term “at least” is synonymous with “greater than or equal to”.

[0028] The term “not greater than” is synonymous with “less than or equal to”.

[0029] As used herein, “at least one of’ is synonymous with “one or more of’. For example, the phrase “at least one of A, B, and C” means any one of A, B, or C, or any combination of any two or more of A, B, or C. For example, “at least one of A, B, and C” includes A alone; or B alone; or C alone; or A and B; or A and C; or B and C; or all of A, B, and C.

[0030] The term “adjacent” means proximate to but not in direct contact with.

[0031] The term “includes” is synonymous with “comprises”.

[0032] As used herein, the terms “parallel” or “substantially parallel” mean a relative angle as between two objects (if extended to theoretical intersection), such as elongated objects and including reference lines, that is from 0° to 5°, or from 0° to 3°, or from 0° to 2°, or from 0° to 1°, or from 0° to 0.5°, or from 0° to 0.25°, or from 0° to 0.1°, inclusive of the recited values.

[0033] As used herein, the terms “perpendicular” or “substantially perpendicular” mean a relative angle as between two objects at their real or theoretical intersection is from 85° to 90°, or from 87° to 90°, or from 88° to 90°, or from 89° to 90°, or from 89.5° to 90°, or from 89.75° to 90°, or from 89.9° to 90°, inclusive of the recited values.

[0034] The term “optical” means pertaining to or associated with light and/or vision. For example, an optical element, article, or device can be chosen from ophthalmic elements, articles, and devices, display elements, articles, and devices, visors, windows, and mirrors.

[0035] The term “ophthalmic” means pertaining to or associated with the eye and vision. Non-limiting examples of ophthalmic articles or elements include corrective and non-corrective lenses, including single vision or multi-vision lenses, which may be either segmented or non-segmented multi-vision lenses (such as, but not limited to, bifocal lenses, trifocal lenses, and progressive lenses), as well as other elements used to correct, protect, or enhance (cosmetically or otherwise) vision, including without limitation, contact lenses, intra-ocular lenses, magnifying lenses, and protective lenses or visors.

[0036] As used herein, the terms “lens” and “lenses” mean and encompass at least individual lenses, lens pairs, partially formed (or semi-finished) lenses, fully formed (or finished) lenses, and lens blanks.

[0037] As used herein, the term "transparent", such as used in connection with a substrate, film, material, and/or coating, means that the indicated substrate, film, material, and/or coating has the property of transmitting light without appreciable scattering so that objects lying beyond are visibly observable.

[0038] As used herein, the term "coating" means a supported film derived from a flowable coating material, which can optionally have a uniform thickness, and specifically excludes polymeric sheets. The terms "layer" and "film" each encompass both coatings (such as a coating layer or a coating film) and sheets, and a layer can include a combination of separate layers, including sub-layers and/or over-layers. The verb "coating" means, within appropriate context, the process of applying a coating material (or materials) to the substrate to form a coating (or coating layer).

[0039] As used herein, the terms "cure", "cured", and related terms, mean that at least a portion of the polymerizable and/or crosslinkable components that form a curable composition are at least partially polymerized and/or crosslinked. In accordance with some examples, the degree of crosslinking can range from 5% to 100% of complete crosslinking. In accordance with some further examples, the degree of crosslinking can range from 30% to 95%, such as 35% to 95%, or 50% to 95%, or 50% to 85% of complete crosslinking. The degree of crosslinking can range between any combination of these recited lower and upper values, inclusive of the recited values.

[0040] As used herein, the term **"IR"** means infrared, such as infrared radiation. The term "infrared radiation" means electromagnetic radiation having a wavelength in the range of greater than 780 nm to 1,000,000 nm.

[0041] As used herein, the term "UV" means ultraviolet, such as ultraviolet radiation. The terms "ultraviolet radiation" and "ultraviolet light" mean electromagnetic radiation having a wavelength in the range of 100 nm to less than 380 nm.

[0042] The discussion of the invention may describe certain features as being "particularly" or "preferably" within certain limitations (e.g., "preferably", "more preferably", or "even more preferably", within certain limitations). It is to be understood that the invention is not limited to these particular or preferred limitations but encompasses the entire scope of the disclosure.

[0043] The invention comprises, consists of, or consists essentially of the following examples of the invention, in any combination. Various examples of the invention may be

discussed separately. However, it is to be understood that this is simply for ease of illustration and discussion. In the practice of the invention, one or more aspects of the invention described in one example can be combined with one or more aspects of the invention described in one or more of the other examples.

[0044] With initial reference to FIG. 1, a production line 100 has a guideway 102 configured for supporting at least one optical article transport vehicle 200 (hereinafter referred to as "transport vehicle 200"). The production line 100 of the present invention can, with some examples, be used for the production of optical articles, such as lenses. Examples of optical articles that can be processed on the production line 100 of the present invention include, but are not limited to, optical lenses, ophthalmic lenses, and/or prescription lenses, which in each case can be finished lenses, unfinished lenses, or lens blanks. In some examples, the production line 100 of the present invention can be at least partially automated and optionally incorporated into art-recognized product tracking and control systems.

[0045] The guideway 102 may have a closed loop configuration or an open configuration. In a closed loop configuration, such as shown in FIG. 1, each transport vehicle 200 is movable in an infinite loop, while an open configuration (not shown) requires loading each transport vehicle 200 at a first end of the production line 100 and unloading each transport vehicle 200 at a second end of the production line 100. In some examples, the guideway 102 may be a moving belt, a track, or other moving mechanism. A position of the transport vehicle 200 may be fixed on the moving guideway 102. Alternatively, the transport vehicle 200 may be movable along the moving guideway 102. In other examples, the guideway 102 may be a stationary track with the transport vehicle 200 movable along the guideway 102. Each transport vehicle 200 may be configured for uni-directional or bi-directional movement along the guideway 102.

[0046] With continued reference to FIG. 1, the exemplary guideway 102 has one or more track sections 102a, one or more turn sections 102b, and one or more merging/diverging sections 102c. The guideway 102 may have a modular layout, wherein the arrangement of the one or more track sections 102a, one or more turn sections 102b, and one or more merging/diverging sections 102c can be changed to change a layout of the guideway 102. In some examples, the track sections 102a may be linear or curved, and may extend in a single plane or may extend from a first vertical plane to a second vertical plane. In some examples,

the one or more turn sections **102b** may be turns having constant or increasing/decreasing radius.

[0047] With continued reference to **FIG. 1,** the production line **100** has a plurality of processing stations **104** positioned along the guideway **102.** Each processing station **104** is configured for performing a predetermined processing step on an optical article carried by the transport vehicle **200.**

[0048] With continued reference to **FIG. 1,** at least one of the processing stations **104** may be a pre-treatment station **104a,** such as a plasma chamber. With some examples, the pre-treatment station **104a** may be a pass-through processing station wherein at least a portion of the transport vehicle **200,** along with the optical article carried thereon, moves through the pre-treatment station **104a.** The plasma surface treatment conducted within the pre-treatment station **104a** can be selected from one or more art-recognized plasma surface treatment methods including, but not limited to, corona treatment, atmospheric plasma treatment, atmospheric-pressure treatment, flame plasma treatment, and/or chemical plasma treatment. With some examples, the surface treatment conducted in the chamber is an oxygen plasma treatment.

[0049] The surface treatment process in the pre-treatment station **104a** involves, with some examples, treating the surface of an optical substrate to promote wetting and enhance adhesion of a coating that is subsequently applied to and formed thereon. Plasma treatments, including corona treatments, provide a clean and efficient method of altering the surface properties of an optical substrate, such as roughening and/or chemically altering one or more surfaces thereof, without altering the bulk properties of the optical substrate.

[0050] With continued reference to **FIG. 1,** at least one of the processing stations **104** may be a washing/drying station **104b.** With some examples, the washing/drying station **104b** may be a pass-through processing station wherein at least a portion of the transport vehicle **200,** along with the optical article carried thereon, moves through the washing/drying station **104b.** The washing/drying station **104b** may have high pressure spray nozzles which spray a cleaning agent, such as deionized water, to clean the surface of the optical article. In some examples, the washing parameters of the washing/drying station **104b,** such as liquid pressure and washing time, can be programmable and can vary based on parameters, such as the type and/or size of the optical substrate, plasma treatment in the pre-treatment station **104a,** and/or subsequent coating processes. Following washing, the optical article can, with some

examples, be dried in the washing/drying station **104b** by one or more drying methods including, but not limited to, high speed air nozzle(s), which can be filtered air nozzles. The drying parameters can be programmed in a manner similar to those associated with the washing parameters, with some examples.

[0051] With continued reference to **FIG. 1,** the production line **100** may have at least one coating station **104c** configured to apply a coating material on at least one surface of the optical article. In some examples, the coating station **104c** may have a spin coating apparatus, or any other coating apparatus configured for applying a coating on at least one surface of the optical article. For example, the coating station **104c** may have an inkjet printing apparatus having one or more print heads configured to controllably discharge atomized droplets of coating material onto one or more coating surfaces of the optical article. The coating station **104c** may have a controller (not shown) for controlling the operation of the coating apparatus. For example, the controller may be configured for controlling the printing operations of the one or more print heads.

[0052] With continued reference to **FIG. 1,** at least one of the processing stations **104** may be a curing station **104d** for selectively and independently curing (such as at least partially curing) each coating applied to the optical article by the coating station **104c.** The curing station **104d** may be at least one of: (i) a thermal curing station; (ii) a UV curing station; (iii) an IR curing station; and (iv) combinations of at least two of (i), (ii), and (iii). The curing time within the curing station **104d** can also vary depending on, for example, the particular coating. Each curing station **104d,** with some examples, can include therein an atmosphere selected from an inert atmosphere (such as, but not limited to, argon and/or nitrogen) and/or a reactive atmosphere (such as, but not limited to, oxygen, CO, and/or $C0_2$).

[0053] With continued reference to **FIG. 1,** at least one of the processing stations **104** may be an inspection station **104e** configured for determining at least one characteristic of the optical article, such as the size or color of the optical article, or the presence or absence of at least one identifying indicia on at least one surface of the optical article. In some examples, the identification station **104e** has at least one sensor for identifying at least one characteristic of the optical article. For example, the at least one sensor may be an optical sensor, such as a camera. The optical sensor may be configured to capture an image of the optical article and determine at least one characteristic of the optical article based on the properties of the image.

[0054] With continued reference to **FIG. 1,** at least one of the processing stations **104** may be a loading/unloading station **104f.** In some examples, empty transport vehicles **200** may be loaded with optical articles, while finished optical articles may be unloaded from the production line **100.** In some examples, separate loading and unloading stations may be provided.

[0055] Each transport vehicle **200** may be configured to be independently moved along the guideway **102** between various processing stations **104.** In some examples, the production line **100** may be configured such that a first portion of the transport vehicles **200** move through a first subset of the processing stations **104,** while a second portion of the transport vehicles **200** move through a second subset of the processing stations **104.** In some examples, the first and second subsets of processing stations **104** may be mutually exclusive. In other examples, the first and second subsets of processing stations **104** may at least partially overlap.

[0056] With reference to **FIG. 2,** a portion of the guideway **102** for use with the production line **100** is illustrated in detail. In some examples, the guideway **102** has a guide channel **106** defined by a pair of rails **108.** In other examples, the guideway **102** may be a single rail **108.** The guide channel **106** is shaped to receive at least a portion of the transport vehicle **200.** While **FIG. 2** illustrates a linear guideway **102** extending in a single plane, curved guideways **102** and/or guideways **102** extending in more than one plane are also contemplated. In some examples, at least one of the rails **108** of the guideway **102** may provide suspension, guiding, and propelling to the transport vehicles **200.** For example, at least one of the rails **108** may have one or more electromagnets that magnetically interact with permanent magnets in the transport vehicles **200** to provide a vertical suspension force, a lateral guidance force, and a longitudinal propulsive force. Power is supplied to the electromagnets from a power supply **110** via one or more power cables **112.** A controller **114** is configured for selectively energizing the electromagnets to control the movement of the transport vehicles **200** along the guideway **102.** In some examples, the guideway **102** may be a magnetic guideway available from MagneMotion (Rockwell Automation) of Devens, Massachusetts.

[0057] With reference to **FIG. 3,** the exemplary transport vehicle **200** has a carrier base **202** configured for movement along the guideway **102,** such as within the guide channel **106** and/or along the rails **108** (shown in **FIG. 2).** In the illustrated example, the carrier base **202** has a first portion **204** and a second portion **206** separated from the first portion **204** by a gap

208 (shown in FIG. 4). In some examples, at least one post 210 is provided between the first portion 204 and the second portion 206 to separate the two portions from each other, thereby defining the gap 208. The at least one post 210 may be positioned relative to the first portion 204 and the second portion 206 such that the gap 208 extends around at least a portion of an outer perimeter of the post 210. In some examples, the at least one post 210 may be positioned relative to the first portion 204 and the second portion 206 such that the gap 208 extends around the entire outer perimeter of the at least one post 210.

[0058] With reference to FIG. 4, the gap 208 is dimensioned such that at least one of the rails 108 (shown in FIG. 2) can be fitted between an upper surface of the first portion 204 and a lower surface of the second portion 206. For example, the gap 208 may be dimensioned such that both rails 108 can be fitted on opposite sides of the at least one post 210 between the upper surface of the first portion 204 and the lower surface of the second portion 206. Desirably, the gap 208 is larger than a thickness of the rails 108 such that the first portion 204 and the second portion 206 are not in direct physical contact with the rails 108.

[0059] In some examples, at least a portion of the carrier base 202 has a magnetic flux source for magnetically interacting with the guideway 102. The magnetic flux source may be at least one permanent magnet 209 in the first portion 204, the second portion 206, and/or the post 210 to magnetically interact with the electromagnet in the guideway 102 and provide a vertical suspension force, a lateral guidance force, and a longitudinal propulsive force to the transport vehicle 200. In examples where the transport vehicle 200 is adapted for movement along the guideway 102 configured as a conveyor belt, the carrier base 202 may have an appropriate structure for mechanically interacting with the conveyor belt. For example, the carrier base 202 may have one or more wheels, bearings, or other mechanical structures for interacting with the conveyor belt.

[0060] With reference to FIG. 3, the transport vehicle 200 has a frame 212 connected to the carrier base 202. The frame 212 may be removably or non-removably connected to the carrier base 202. In some examples, the frame 212 is removably connected to the first portion 204 of the carrier base 202 by one or more fasteners 214. In other examples, the frame 212 is non-removably connected to the first portion 204 of the carrier base 202, such as by welding, adhesive, or other permanent connection means. The frame 212 may be monolithically formed with the first portion 204 and/or the second portion 206 of the carrier base 202. The frame

212 may be configured for supporting one or more mechanisms for carrying the optical article, as described herein.

[0061] With continued reference to **FIG. 3,** the transport vehicle **200** has a pair of gripping arms **216** configured for holding an optical article **300** during transport. Each gripping arm **216** has a first end **216a** connected to the transport vehicle **200** and a second end **216b** protruding from the transport vehicle **200.** In some examples, each gripping arm **216** is connected at its first end **216a** to the carrier base **202,** such as the first portion **204** of the carrier base **202.** In other examples, each gripping arm **216** is connected at its first end **216a** to the frame **212.** The gripping arms **216** are movable between a closed position **(FIG. 3)** and an open position **(FIG. 5).** In the closed position, the gripping arms **216** are configured for holding the optical article **300** therebetween, while, in the open position, the optical article **300** is released from the gripping arms **216.** The gripping arms **216** protrude relative to the carrier base **202** in a direction substantially perpendicular to a direction of travel of the carrier base **202** identified by arrow A in **FIG. 3.**

[0062] The gripping arms **216** may be shaped to prevent accumulation of liquid, such as water thereon, and to allow for easier wicking of the water from their surface during the drying process. While **FIG. 3** shows the gripping arms **216** shaped in accordance with one preferred and non-limiting embodiment, other shapes are not precluded. For example, the gripping arms **216** may be comprised of flat or rounded surfaces and/or edges, or a combination of flat or rounded surfaces and/or edges.

[0063] With continued reference to **FIG. 3,** each of the gripping arms **216** has a first portion **218** at the first end **216a** and a second portion **220** at the second end **216b.** The first portion **218** is connected to the second portion **220** by a transition portion **222.** In some examples, the first portion **218** may be offset relative to the second portion **220.** For example, a plane defined by the first portion **218** may be offset by a predetermined distance D (shown in **FIG. 4)** from a plane defined by the second portion **218.** In such examples, the transition portion **222** is connected to the first portion **218** such that a first angle **a** is defined between the first portion **218** and the transition portion **222.** The first angle **a** may be in the range of 30° to 60°, preferably 45° to 55°, more preferably 47° to 50°. Similarly, the transition portion **222** is connected to the second portion **220** such that a second angle β is defined between the second portion **220** and the transition portion **222.** The second angle β may be in the range of 30° to 60°, preferably 45° to 55°, more preferably 47° to 50°.

[0064] With continued reference to **FIG. 3,** the gripping arms **216** may be configured to hold the optical article **300** at a predetermined distance X away from the carrier base **202.** In some examples, the predetermined distance X may be measured from a center of the carrier base **202** to a center of the optical article **300.** In some examples, the predetermined distance X may be in the range of 200 mm (7.87 in.) to 300 mm (11.81 in), preferably 215 mm (8.46 in.) to 250 mm (9.84 in.), more preferably 220 mm (8.66 in.) to 230 mm (9.05 in.) from the center of the carrier base **202** to the center of the optical article **300.** The predetermined distance X is selected such that the second end **216b** of the gripping arms **216,** and therefore the optical article **300,** is maintained away from the guideway **102** to allow for processing of the optical article **300** within various processing stations **104** (shown in **FIG. 1)** without interference with the guideway **102.** For example, the predetermined distance X may be selected such that the carrier base 202 is maintained at a safe distance away from the equipment, such as the electrode, counter-electrode, and high-voltage cabling of a corona discharge machine. Offsetting the optical article **300** from the carrier base **202** by the predetermined distance X allows the optical article **300** to be passed through various processing stations **104** without the need to remove the optical article **300** from the gripping arms **216.**

[0065] With continued reference to **FIG. 3,** the optical article **300** has a forward or top surface **302,** a rearward or bottom surface **304,** and a side surface **306** extending between the top surface **302** and the bottom surface **304.** When the optical article **300** is an ophthalmic lens, the bottom surface **304** is opposed to the eye of an individual wearing the optical article **300,** the side surface **306** typically resides within a supportive frame, and the top surface **302** faces incident light (not shown), at least a portion of which passes through the optical article **300** and into the individual's eye. With some examples, at least one of the top surface **302,** the bottom surface **304,** and the side surface **306** may have various shapes including, but not limited to, round, flat, cylindrical, spherical, planar, substantially planar, plano-concave and/or plano-convex, and curved, including, but not limited to, convex, and/or concave.

[0066] The optical article **300** can be selected from ophthalmic articles or elements, display articles or elements, visors, windows, mirrors, active liquid crystal cell articles or elements, and passive liquid crystal cell articles or elements. Examples of ophthalmic articles or elements include, but are not limited to, corrective and non-corrective lenses, including single vision or multi-vision lenses, which can be either segmented or non-segmented multi-

vision lenses (such as, but not limited to, bifocal lenses, trifocal lenses, and progressive lenses), as well as other elements used to correct, protect, or enhance (cosmetically or otherwise) vision, including without limitation, contact lenses, intra-ocular lenses, magnifying lenses, and protective lenses or visors. Examples of display articles, elements and devices include, but are not limited to, screens, monitors, and security elements, including without limitation, security marks and authentication marks. Examples of windows include, but are not limited to, automotive and aircraft transparencies, filters, shutters, and optical switches. The optical article **300** can comprise a polymeric organic material chosen from thermosetting polymeric organic materials, thermoplastic polymeric organic materials, or a mixture of such polymeric organic materials.

[0067] With reference to **FIG. 3,** each gripping arm **216** has a pair of projections **224** at the second end **216b.** The projections **224** are spaced apart along a longitudinal length of the gripping arms **216** and are configured for contacting at least a portion of the optical article **300** when the gripping arms **216** are in the closed position. The projections **224** may protrude upwardly relative to an upper surface **226** of each gripping arm **216** in a direction of arrow **B.** In some examples, the projections **224** may also protrude inwardly from an inner lateral surface **228** of each gripping arm **216** in a direction of arrow C. The projections **224** may be removably or non-removably connected to the gripping arms **216.** In some examples, each projection **224** is removably connected to the gripping arm **216** to allow replacement of the projections **224** without replacing the gripping arms **216.** In other examples, each projection **224** is permanently and non-removably connected to the respective gripping arm **216** such that replacement of the projections **224** requires replacement of the gripping arms **216.**

[0068] Each projection **224** has a base **230** that is connected to the gripping arm **216.** In some examples, the base **230** may have a substantially cylindrical shape or any other geometric shape. Each projection **224** further has a nub **232** that protrudes upwardly from the base **230** and relative to the upper surface **226** of the gripping arm **216.** In some examples, the nub **232** may have a pyramidal shape, a cylindrical shape, or any other geometric shape.

[0069] The projections **224** are configured to support the optical article **300** in one of two configurations. In a first configuration, the side surface **306** of the optical article **300** is supported on a side surface **234** of the projections **224,** such as the side surface **234** of the base **230** and/or the nubs **232.** Uncoated optical articles **300** are desirably supported in the first configuration because the body of the optical article **300** is held securely between the gripping

arms **216** due to surface-to-surface contact between the side surface **306** of the optical article **300** and the side surface **234** of the projections **224.** In a second configuration, the bottom surface **304** of the optical article **300** is supported on a top surface **236** of the projections **224,** such as the top surface **236** of the nubs **232.** In the second configuration, the side surface **306** and the top surface **302** of the optical article **300** do not contact the projections **224** or the gripping arms **216** to eliminate transfer of uncured coating material from the optical article **300** to the projections **224** or the gripping arms **216.**

[0070] The gripping arms **216** may be made from a first material while the projections **224** may be made from a second material different from the first material. For example, the gripping arms **216** may be made from glass-filled nylon, non-glass-filled nylon, polycarbonate, or an amorphous thermoplastic polyetherimide resin commercially available under the trade name ULTEM™. Desirably, the gripping arms **216** are made from a material with low water absorption. The gripping arms **216** may be made using an injection molding process. At least a portion of each projection **224,** such as the base **230** and/or the nub **232,** may be made from an elastomeric material, such as a thermoplastic elastomer material. In some examples, at least a portion of each projection **224** may be made from Santoprene™, available from the ExxonMobil Corporation of Irving, Texas. The projections **224** maybe co-molded with each gripping arm **216.** An interface between the gripping arms **216** and the projections **224** may be water tight.

[0071] With continued reference to **FIG. 3,** the transport vehicle **200** has a closure mechanism **238** for moving the gripping arms **216** between the closed position and the open position. In some examples, the closure mechanism **238** is a pneumatic mechanism. In other examples, the closure mechanism **238** is a mechanical mechanism, an electrical mechanism, an electromechanical mechanism, a hydraulic mechanism, or any combination thereof. The closure mechanism **238** may be configured for biasing the pair of gripping arms **216** to the closed position and moving the gripping arms **216** to the open position when the carrier base 202 is positioned at a predetermined portion of the guideway 102, such as at a docking station of a processing station **104,** as described herein.

[0072] With reference to **FIG. 7,** the closure mechanism **238** is configured as a gas compression spring. The closure mechanism **238** has at least one actuator **240,** a first chamber **242** on a first side of the actuator **240,** and a second chamber **244** on a second side of the actuator **240.** In some examples, the closure mechanism **238** has a pair of actuators **240.** At

least a portion of each gripping arm **216,** such as the second end **216b,** is connected to a separate actuator **240** (shown in **FIG. 3).** The first chamber **242** has a first volume and the second chamber **244** has a second volume, with the second volume being smaller than the first volume. The first chamber **242** is closed to the atmosphere with a first check valve **246** and is in fluid communication with a first side **244a** of the second chamber **244** via a passage **250.** The second chamber **244** is closed to the atmosphere with a second check valve **248.**

[0073] Each actuator **240** is movable between an open position and a closed position within the second chamber **244** between the first side **244a** and a second side **244b** based on a pressure differential between the first side **244a** and the second side **244b.** In some examples, each actuator **240** may be in a normally closed position. In the closed position, a pressure in the first chamber **242** and the first side **244a** of the second chamber **244** is higher than a pressure in the second side **244b** of the second chamber **244** such that the actuator **240** is in a first or closed position. To move the actuator **240** to the open position, high pressure is applied to the second side **244b** of the second chamber **244** such that the pressure in the second side **244b** of the second chamber **244** is higher than the pressure in the first side **244a** of the second chamber **244** and the first chamber **242.** Due to this pressure differential, the actuator **240** moves within the second chamber **244** in a direction of arrow **D.** When the high pressure input to the second side **244b** of the second chamber **244** is closed, the second side **244b** is vented through a vent **252** and/or the second check valve **248** such that the pressure in the first side **244a** of the second chamber **244** and the first chamber **242** moves the actuators **240** in a direction of arrows E.

[0074] With reference to **FIGS. 8-9,** the closure mechanism **238** is configured to move the gripping arms **216** to the open position when the carrier base **202** is positioned at a predetermined portion of the guideway **102,** such as at a docking station **276.** In some examples, the docking station **276** may be associated with one or more processing stations **104** (shown in **FIG. 1).** The gripping arms **216** may be in the normally closed position when the transport vehicle **200** is at any portion of the guideway **102** other than the docking station **276.** Once the transport vehicle **200** is stopped at a docking station **276,** the closure mechanism **238** may be configured to move the gripping arms **216** to the open position due to interaction with at least a portion of the docking station **276.**

[0075] In some examples, the docking station **276** may have at least one pin **277** (shown in **FIGS. 7** and **9)** configured for interacting with the second check valve **248.** In some

examples, the at least one pin **277** may be movable between a first position, wherein the at least one pin **277** is not in direct physical contact with the second check valve **248** and a second position, wherein the at least one pin **277** is in direct physical contact with the second check valve **248.** The docking station **276** is in fluid communication with a pressurized air source (not shown) such that pressurized air may be delivered to the second chamber **244** when the at least one pin **277** interacts with the second check valve **248.** For example, the at least one pin **277** may open the second check valve **248** by pushing the second check valve **248** from a first or closed position to a second or open position. The at least one pin **277** may seal the second check valve **248** after opening the second check valve **248** to prevent the escape of pressurized air therefrom. In some examples, the at least one pin **277** may be configured for venting the second side **244b** of the second chamber **244** by interacting with the vent **252** and/or the second check valve **248.** For example, the pin **277** may partially open the second check valve **248** to allow venting of the second chamber **244.**

[0076] With reference to **FIGS. 5-6,** the transport vehicle **200** may have a secondary closure mechanism **254** to bias the pair of gripping arms **216** to the closed position independently of the closure mechanism **238.** In some examples, the secondary closure mechanism **254** is a spring **256** or a resiliently elastic band with a first end **256a** connected to a first end **216a** of the pair of gripping arms **216** and a second end **216b** of the pair of gripping arms **216.** The secondary closure mechanism **254** may provide a predetermined closing force to maintain the arms in the closed position independently of the closure mechanism **238.**

[0077] With reference to **FIGS. 10-11,** the closure mechanism **238'** is shown in accordance with another example. Similar to the closure mechanism **238** described herein with reference to **FIG. 7,** the closure mechanism **238'** of **FIGS. 10-11** is configured for moving the gripping arms **216** between an open position **(FIG. 10)** and a closed position **(FIG. 11).** Rather than being a pneumatic system, such as the closure mechanism **238** shown in **FIG. 7,** the closure mechanism **238'** of **FIGS. 10-11** is a mechanical system that is biased to a normally closed position by one or more springs. The closure mechanism **238'** has a linkage arrangement that is movable between a first position, wherein the pair of gripping arms **216** is in the closed position **(FIG. 11),** and a second positon, wherein the pair of gripping arms **216** is in the open position **(FIG. 10).**

[0078] With continued reference to **FIGS. 10-11,** the linkage arrangement of the closure mechanism **238'** has a pair of links **258** movable linearly along at least one rod **260.** In some

examples, a pair of parallel rods **260** may be spaced apart and the links **258** may be movable linearly along each of the rods **260.** The gripping arms **216** are connected to the links **258** such that the gripping arms **216** are movable with movement of the links **258.** Each link **258** is movable between a first or closed position **(FIG. 11),** and a second or open positon **(FIG. 10).** In the closed position, the gripping arms **216** are configured for holding the optical article **300** (not shown) therebetween, while, in the open position, the optical article **300** is released from the gripping arms **216.** The links **258** are biased to the closed position by one or more springs **262** or other elastically resilient members. In some examples, the one or more springs **262** may be a pair of springs **262** on outer lateral sides of the links **258.** The one or more springs **262** may be wrapped around the rod **260,** such that a first end of each spring **262** contacts a housing **264,** while a second end of each spring contacts one of the links **258.** Each link **258** has a cam slot (not shown) configured to receive a first end of a pivot link **266.** A second end of each pivot link **266** is pivotally connected to a block **268** at a pivot point **270.** With linear movement of the links **258** along the rods **260,** the second end of the pivot links **266** pivots about the pivot point **270,** while the first end slides linearly within the cam slot. The links **258** can be moved to the open position by an opening mechanism (not shown) urging the links **258** and/or the gripping arms **216** away from each other and against the force of the springs **262.** In some examples, the opening mechanism may act on an opening tab **272** formed on an inner lateral side of the links **258** and/or the gripping arms **216.**

[0079] With reference to **FIG. 3,** the transport vehicle **200** has an alignment mechanism **274** for aligning the transport vehicle **200** relative to a docking station **276** (shown in **FIGS. 8-9)** on the guideway **102.** The alignment mechanism **274** is configured to precisely position the transport vehicle **200** on the guideway **102** relative to the docking station **276** by constraining the transport vehicle 200 to translate along the guideway 102 with a single degree of freedom.

[0080] The alignment mechanism **274** has a slot **278** formed in the frame **212** of the transport vehicle **200** and configured for receiving at least a portion of an alignment rail **280** of the docking station **276.** As shown in **FIG. 3,** the slot **278** extends in a direction that is substantially parallel to a direction of travel of the transport vehicle **200.** In some examples, one or more guide wheels **279** may be provided within the slot **278** for guiding the frame **212** along the alignment rail **280.** With reference to **FIGS. 8-9,** the alignment rail **280** is also positioned substantially parallel to the guideway **102.** In this manner, when the transport

vehicle **200** is aligned with the alignment rail **280,** the movement of the transport vehicle **200** is constrained to translation along the guideway **102** guided by the alignment rail **280.** In some examples, the alignment rail **280** is secured to a frame **284** to constrain the alignment rail **280** relative to the guideway **102.** In some examples, the alignment rail **280** extends along the entire guideway **102.** In some examples, the alignment rail **280** extends along predetermined portions of the guideway **102,** such as at the docking station **276** of at least one processing station **104.**

[0081] With reference to **FIG. 3,** the alignment mechanism **274** further has at least one centering element **282** configured for engaging the alignment rail **280.** In some examples, the at least one centering element **282** may be a pair of rotatable cam followers that straddle the alignment rail **280** on opposite lateral sides of the alignment rail **280,** such as shown in **FIG. 9**. In other examples, three or more rotating cam followers may be provided. **FIG. 3** shows three centering elements **282** arranged in a staggered orientation with one centering element **282** is configured to engage a first lateral side of the alignment rail **280,** and a pair of centering elements is configured to engage a second lateral side of the alignment rail **280** (see **FIG. 9).**

[0082] With continued reference to **FIG. 3,** the transport vehicle **200** has at least one arm position indicator **286** configured for indicating a position of at least one of the gripping arms **216.** In some examples, the at least one arm position indicator **286** may be associated with at least one of the gripping arms **216.** In some examples, the at least one arm position indicator **286** is connected to one of the gripping arms **216.** In other examples, each of the gripping arms **216** has at least one arm position indicator **286.** The at least one arm position indicator **286** may be connected to at least a portion of the gripping arms **216,** such as the first portion **218,** the second portion **220,** and/or the transition portion **222.** In some examples, the at least one arm position indicator **286** protrudes upwardly from an upper surface **226** of the first portion **218** of at least one gripping arm **216.**

[0083] With reference to **FIG. 9,** the at least one arm position indicator **286** is a permanent magnet that is configured for magnetically interacting with at least one position sensor **288** on the frame **284** and/or the alignment rail **280.** In some examples, the at least one position sensor **288** may be a Hall effect sensor that varies its output signal based on a sensed magnetic field of the at least one arm position indicator **286.** For example, the signal strength of the at least one positon sensor **288** may be within a first range when the gripping arms **216** are in a first or open position, and the signal strength may increase or decrease to a second range when the

gripping arms **216** are in a second or closed position. In some examples, a pair of position sensors **288** may be provided, wherein a first of the pair of position sensors **288** is configured to detect the open position of the gripping arms **216,** while a second of the pair of sensors **288** is configured to detect the closed position of the gripping arms **216.**

[0084] Having described the structure of the transport vehicle **200,** an exemplary method of transporting the optical article **300** along the guideway **102** between various processing stations **104** will now be described. Initially, an empty transport vehicle **200** is loaded with an optical article **300** at a loading/unloading station **104f.** The empty transport vehicle **200** may stop at a docking station **276** of the loading/unloading station **104f,** wherein the gripping arms **216** are moved from a closed position to an open position to allow for loading of the optical article **300** therebetween. For example, the closure mechanism **238** may move the gripping arms **216** to the open position when the carrier base **202** of the transport vehicle **200** is positioned at the docking station **276** of the loading/unloading station **104f.** The docking station **276** is in fluid communication with a pressurized air source (not shown) such that pressurized air may be delivered to the second chamber **244** when the at least one pin **277** interacts with the second check valve **248.** High pressure is applied to the second side **244b** of the second chamber **244** such that the pressure in the second side **244b** of the second chamber **244** is higher than the pressure in the first side **244a** of the second chamber **244** and the first chamber **242.** Due to this pressure differential, the actuators **240** move within the second chamber **244** to open the gripping arms **216.**

[0085] After positioning the optical article **300** such that the side surface **306** of the optical article **300** is aligned with a side surface **234** of the projections **224,** such as the side surface **234** of the base **230** and/or the nubs **232,** the gripping arms **216** may be moved to the closed position, by venting the second chamber **244,** and allowing the actuators **240** to move to the closed position due to a pressure differential between the first chamber **242** and the second chamber **244.**

[0086] With the optical article **300** securely held between the gripping arms **216,** the transport vehicle **200** may be guided along the guideway **102** between one or more processing stations **104.** For example, the transport vehicle **200** may transport the optical article **300** through the pre-treatment station **104a.** As described herein, the pre-treatment station **104a** may be a pass-through processing station wherein the optical article **300** moves through the plasma surface treatment machine, while the carrier base **202** is outside of the machine. The

positioning of the gripping arms **216** allows the optical article **300** to move through the pre-treatment station **104a** without having to remove the optical article **300** from the transport vehicle 200.

[0087] After treating the surface of the optical article **300** in the pre-treatment station **104a,** the transport vehicle **200** may guide the optical article **300** through the washing/drying station **104b.** Similar to the pre-treatment station **104a,** the washing/drying station **104b** may be a pass-through processing station wherein the optical article **300** moves through the washing/drying machine, while the carrier base **202** is outside of the machine. The washing/drying station **104b** may have high pressure spray nozzles which spray a cleaning agent, such as deionized water, to clean the surface of the optical article **300,** after which the optical article **300** is dried, such as with forced air nozzles. The gripping arms **216** may be shaped to prevent accumulation of water thereon, and to allow for easier wicking of the water from their surface during the drying process.

[0088] After washing and drying the optical article **300,** the transport vehicle **200** may guide the optical article **300** to a coating station **104c.** In some examples, the coating station **104c** has a docking station **276** wherein optical article **300** is unloaded from the transport vehicle **200** and loaded into the coating station **104c** for coating. After at least one surface of the optical article **300** has been coated, the coated optical article **300** is loaded onto the same transport vehicle **200** that delivered the optical article **300** to the coating station **104c,** or onto another empty transport vehicle **200.** The coated optical article **300** may be loaded on the gripping arms **216** such that the bottom surface **304** of the optical article **300** is supported on a top surface **236** of the projections **224,** such as the top surface **236** of the nubs **232.** In this manner, the side surface **306** and the top surface **302** of the optical article **300** do not contact the projections **224** or the gripping arms **216** to eliminate transfer of uncured coating material from the optical article **300** to the projections **224** or the gripping arms **216.**

[0089] The transport vehicle **200** may guide the coated optical article **300** to a curing station **104d.** Similar to the pre-treatment station **104a** and the washing/drying station **104b,** the curing station **104d** may be a pass-through processing station wherein the optical article **300** moves through the curing machine, while the carrier base **202** is outside of the machine. In some examples, the cured optical article **300** may undergo several additional processing steps, such as additional washing/drying, coating, and/or curing steps. After the final processing step, the finished optical article **300** may be inspected at the inspection station **104e**

before the optical article **300** is unloaded from the production line **100** at the loading/unloading station **104f.**

[0090] In further examples, the optical article transport vehicle can be characterized by one or more of the following clauses:

[0091] Clause 1: An article transport vehicle comprising: a carrier base configured for movement along a guideway; a pair of gripping arms, each gripping arm having a first end connected to the carrier base and a second end protruding from the carrier base, the pair of gripping arms movable between a closed position configured for holding an article and an open position configured for releasing the article; and a closure mechanism for moving the pair of gripping arms between the closed position and the open position, the closure mechanism biasing the pair of gripping arms to the closed position and moving the pair of gripping arms to the open position when the carrier base is positioned at a predetermined portion of the guideway.

[0092] Clause 2: The article transport vehicle of clause 1, wherein the closure mechanism comprises an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator.

[0093] Clause 3: The article transport vehicle of clause 2, wherein the first chamber has a first volume and the second chamber has a second volume, wherein the second volume is smaller than the first volume.

[0094] Clause 4: The article transport vehicle of clause 2 or 3, wherein, in the closed position, a pressure in the first chamber is higher than a pressure in the second chamber such that the actuator is in a first position, and wherein, in the open positon, the pressure in the first chamber is lower than the pressure in the second chamber such that the actuator is in a second position.

[0095] Clause 5: The article transport vehicle of any of clauses 1-4, wherein the closure mechanism comprises a linkage arrangement movable between a first position, wherein the pair of gripping arms is in the closed position, and a second positon, wherein the pair of gripping arms is in the open position.

[0096] Clause 6: The article transport vehicle of clause 5, wherein the linkage arrangement is biased to the first position by at least one biasing spring.

[0097] Clause 7: The article transport vehicle of any of clauses 1-6, wherein the second end of each gripping arm has a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm.

[0098] Clause 8: The article transport vehicle of clause 7, wherein at least one of the pair of gripping arms is made from a first material and at least one of the projections is made from a second material different from the first material.

[0099] Clause 9: The article transport vehicle of any of clauses 1-8, further comprising a secondary closure mechanism to bias the pair of gripping arms to the closed position.

[00100] Clause 10: The article transport vehicle of clause 9, wherein the secondary closure mechanism is a spring or a resiliently elastic band.

[00101] Clause 11: The article transport vehicle of any of clauses 1-10, further comprising at least one arm position indicator on at least one of the pair of gripping arms, the at least one arm position indicator configured for indicating a position of the at least one of the pair of gripping arms.

[00102] Clause 12: The article transport vehicle of clause 11, wherein the at least one arm position indicator is a permanent magnet.

[00103] Clause 13: The article transport vehicle of any of clauses 1-12, further comprising at least one centering element configured for engaging an alignment rail along at least a portion of the guideway for centering the carrier base relative to the guideway.

[00104] Clause 14: The article transport vehicle of any of clauses 1-13, wherein the pair of gripping arms protrude relative to the carrier base in a direction substantially perpendicular to a direction of travel of the carrier base.

[00105] Clause 15: The article transport vehicle of any of clauses 1-14, wherein the carrier base comprises a magnetic flux source.

[00106] Clause 16: A production line comprising: a guideway; one or more processing stations positioned along the guideway; and one or more article transport vehicles configured for movement along at least a portion of the guideway, each of the one or more article transport vehicles comprising a carrier base; a pair of gripping arms, each gripping arm having a first end connected to the carrier base and a second end protruding from the carrier base, the pair of gripping arms movable between a closed position configured for holding an article and an open position configured for releasing the article; and a closure mechanism for moving the pair of gripping arms between the closed position and the open position, the closure

mechanism biasing the pair of gripping arms to the closed position and moving the pair of gripping arms to the open position when the carrier base is positioned at a predetermined portion of the guideway.

[00107] Clause 17: The production line of clause 16, wherein the closure mechanism comprises an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator.

[00108] Clause 18: The production line of clause 17, wherein the first chamber has a first volume and the second chamber has a second volume, wherein the second volume is smaller than the first volume.

[00109] Clause 19: The production line of clause 17 or 18, wherein, in the closed position, a pressure in the first chamber is higher than a pressure in the second chamber such that the actuator is in a first position, and wherein, in the open positon, the pressure in the first chamber is lower than the pressure in the second chamber such that the actuator is in a second position.

[00110] Clause 20: The production line of any of clauses 16-19, wherein the closure mechanism comprises a linkage arrangement movable between a first position, wherein the pair of gripping arms is in the closed position, and a second positon, wherein the pair of gripping arms is in the open position.

[00111] Clause 21: The production line of clause 20, wherein the linkage arrangement is biased to the first position by at least one biasing spring.

[00112] Clause 22: The production line of any of clauses 16-21, wherein the second end of each gripping arm has a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm.

[00113] Clause 23: The production line of clause 22, wherein at least one of the pair of gripping arms is made from a first material and at least one of the projections is made from a second material different from the first material.

[00114] Clause 24: The production line of any of clauses 16-23, further comprising a secondary closure mechanism to bias the pair of gripping arms to the closed position.

[00115] Clause 25: The production line of clause 24, wherein the secondary closure mechanism is a spring or a resiliently elastic band.

[00116] Clause 26: The production line of any of clauses 16-25, further comprising at least one arm position indicator on at least one of the pair of gripping arms, the at least one arm

position indicator configured for indicating a position of the at least one of the pair of gripping arms.

[00117] Clause 27: The production line of clause 26, wherein the at least one arm position indicator is a permanent magnet.

[00118] Clause 28: The production line of any of clauses 16-27, further comprising at least one centering element configured for engaging an alignment rail along at least a portion of the guideway for centering the carrier base relative to the guideway.

[00119] Clause 29: The production line of any of clauses 16-28, wherein the pair of gripping arms protrude relative to the carrier base in a direction substantially perpendicular to a direction of travel of the carrier base.

[00120] Clause 30: The production line of any of clauses 16-29, wherein the carrier base comprises a magnetic flux source.

[00121] Clause 31: The production line of any of clauses 16-30, wherein the guideway has an open loop configuration or a closed loop configuration.

[00122] Clause 32: The production line of any of clauses 16-31, wherein the guideway is a moving belt, a track, or a combination thereof.

[00123] Clause 33: The production line of any of clauses 16-32, wherein the guideway has a guide channel positioned between a pair of rails.

[00124] Clause 34: The production line of any of clauses 16-33, wherein the guideway has one or more electromagnets that magnetically interact with the one or more article transport vehicles.

[00125] Clause 35: The production line of any of clauses 16-34, wherein the one or more processing

[00126] Clause 36: The production line of any of clauses 16-35, stations is a pre-treatment station having a plasma chamber.

[00127] Clause 37: The production line of any of clauses 16-36, wherein the one or more processing stations is a drying station.

[00128] Clause 38: The production line of any of clauses 16-37, wherein the one or more processing stations is a washing station.

[00129] Clause 39: The production line of any of clauses 16-38, wherein the one or more processing stations is a coating station.

[00130] Clause 40: The production line of any of clauses 16-39, wherein the one or more processing stations is a curing station.

[00131] Clause 41: The production line of any of clauses 16-40, wherein the one or more processing stations is an inspection station.

[00132] Clause 42: The production line of any of clauses 16-41, wherein the one or more processing stations is a loading/unloading station.

[00133] Clause 43: A method of transporting articles along a guideway, the method comprising: providing one or more article transport vehicles configured for movement along at least a portion of the guideway, each of the one or more article transport vehicles comprising a carrier base; a pair of gripping arms, each gripping arm having a first end connected to the carrier base and a second end protruding from the carrier base, the pair of gripping arms movable between a closed position configured for holding an article and an open position configured for releasing the article; and operating a closure mechanism when the carrier base is positioned at a predetermined portion of the guideway to move the pair of gripping arms from the closed position to the open position.

[00134] Clause 44: The method of clause 43, wherein the closure mechanism comprises an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator.

[00135] Clause 45: The method of clause 44, wherein the first chamber has a first volume and the second chamber has a second volume, wherein the second volume is smaller than the first volume.

[00136] Clause 46: The method of clause 44 or 45, wherein, in the closed position, a pressure in the first chamber is higher than a pressure in the second chamber such that the actuator is in a first position, and wherein, in the open positon, the pressure in the first chamber is lower than the pressure in the second chamber such that the actuator is in a second position.

[00137] Clause 47: The method of any of clauses 43-46, wherein the closure mechanism comprises a linkage arrangement movable between a first position, wherein the pair of gripping arms is in the closed position, and a second positon, wherein the pair of gripping arms is in the open position.

[00138] Clause 48: The method of clause 47, wherein the linkage arrangement is biased to the first position by at least one biasing spring.

[00139] Clause 49: The method of any of clauses 43-48, wherein the second end of each gripping arm has a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm.

[00140] Clause 50: The method of clause 49, wherein at least one of the pair of gripping arms is made from a first material and at least one of the projections is made from a second material different from the first material.

[00141] Clause 51: The method of any of clauses 43-50, further comprising a secondary closure mechanism to bias the pair of gripping arms to the closed position.

[00142] Clause 52: The method of clause 51, wherein the secondary closure mechanism is a spring or a resiliently elastic band.

[00143] Clause 53: The method of any of clauses 43-52, further comprising at least one arm position indicator on at least one of the pair of gripping arms, the at least one arm position indicator configured for indicating a position of the at least one of the pair of gripping arms.

[00144] Clause 54: The method of clause 53, wherein the at least one arm position indicator is a permanent magnet.

[00145] Clause 55: The method of any of clauses 43-54, further comprising at least one centering element configured for engaging an alignment rail along at least a portion of the guideway for centering the carrier base relative to the guideway.

[00146] Clause 56: The method of any of clauses 43-55, wherein the pair of gripping arms protrude relative to the carrier base in a direction substantially perpendicular to a direction of travel of the carrier base.

[00147] Clause 57: The method of any of clauses 43-56, wherein the carrier base comprises a magnetic flux source.

[00148] The present invention has been described with reference to specific details of particular examples thereof. It is not intended that such details be regarded as limitations upon the scope of the invention except insofar as and to the extent that they are included in the accompanying claims.

WHAT IS CLAIMED IS:

1. An article transport vehicle comprising:

a carrier base configured for movement along a guideway;

a pair of gripping arms, each gripping arm having a first end connected to the carrier base and a second end protruding from the carrier base, the pair of gripping arms movable between a closed position configured for holding an article and an open position configured for releasing the article; and

a closure mechanism for moving the pair of gripping arms between the closed position and the open position, the closure mechanism biasing the pair of gripping arms to the closed position and moving the pair of gripping arms to the open position when the carrier base is positioned at a predetermined portion of the guideway.

2. The article transport vehicle of claim 1, wherein the closure mechanism comprises an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator.

3. The article transport vehicle of claim 2, wherein the first chamber has a first volume and the second chamber has a second volume, wherein the second volume is smaller than the first volume.

4. The article transport vehicle of claim 2, wherein, in the closed position, a pressure in the first chamber is higher than a pressure in the second chamber such that the actuator is in a first position, and wherein, in the open positon, the pressure in the first chamber is lower than the pressure in the second chamber such that the actuator is in a second positon.

5. The article transport vehicle of claim 1, wherein the closure mechanism comprises a linkage arrangement movable between a first position, wherein the pair of gripping arms is in the closed position, and a second positon, wherein the pair of gripping arms is in the open position.

6. The article transport vehicle of claim 5, wherein the linkage arrangement is biased to the first position by at least one biasing spring.

7. The article transport vehicle of any of claims 1-6, wherein the second end of each gripping arm has a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm.

8. The article transport vehicle of claim 7, wherein at least one of the pair of gripping arms is made from a first material and at least one of the projections is made from a second material different from the first material.

9. The article transport vehicle of any of claims 1-8, further comprising a secondary closure mechanism to bias the pair of gripping arms to the closed position.

10. The article transport vehicle of claim 9, wherein the secondary closure mechanism is a spring or a resiliently elastic band.

11. The article transport vehicle of any of claims 1-10, further comprising at least one arm position indicator on at least one of the pair of gripping arms, the at least one arm position indicator configured for indicating a position of the at least one of the pair of gripping arms.

12. The article transport vehicle of claim 11, wherein the at least one arm position indicator is a permanent magnet.

13. The article transport vehicle of any of claims 1-12, further comprising at least one centering element configured for engaging an alignment rail along at least a portion of the guideway for centering the carrier base relative to the guideway.

14. The article transport vehicle of any of claims 1-13, wherein the pair of gripping arms protrude relative to the carrier base in a direction substantially perpendicular to a direction of travel of the carrier base.

15. The article transport vehicle of any of claims 1-14, wherein the carrier base comprises a magnetic flux source.

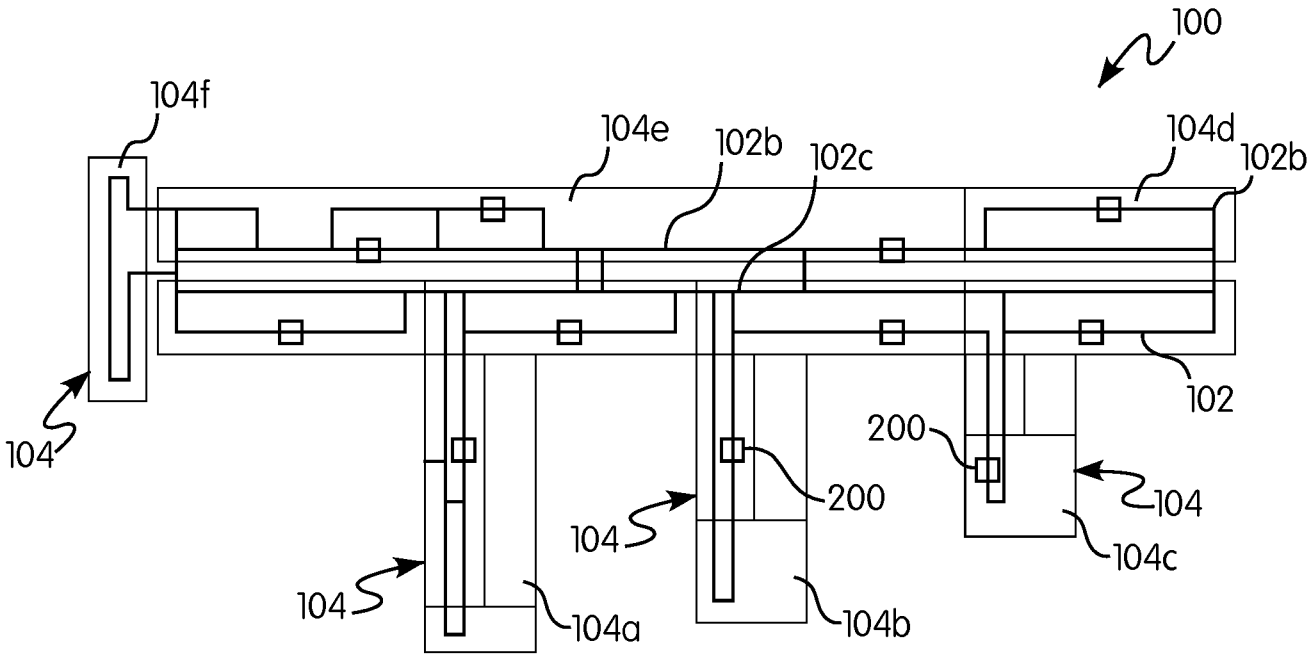
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FIG. 1

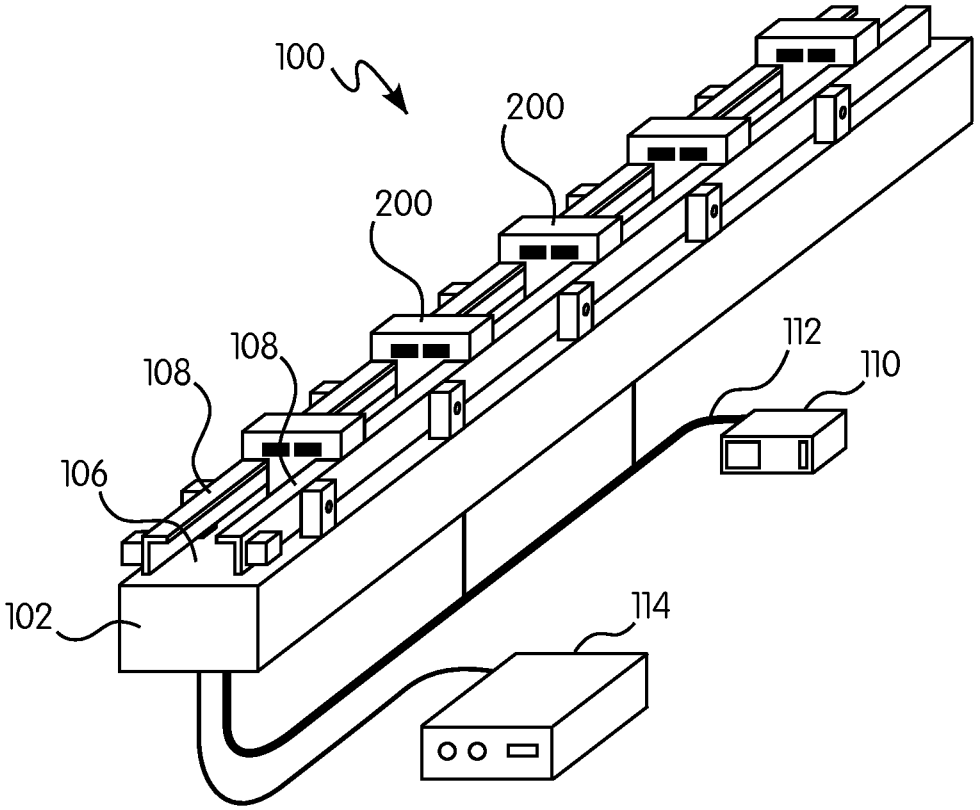
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FIG. 2

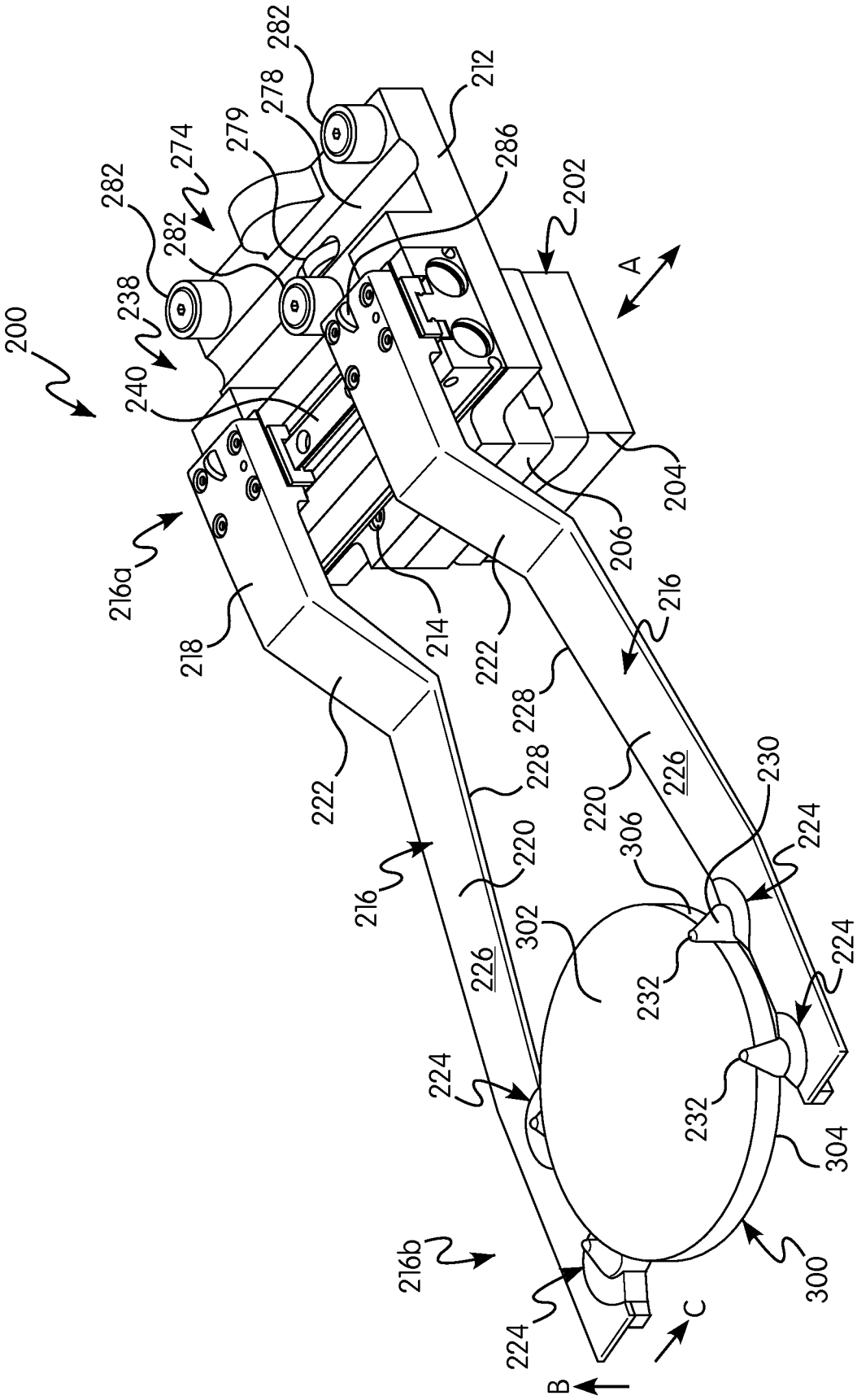
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FIG. 3

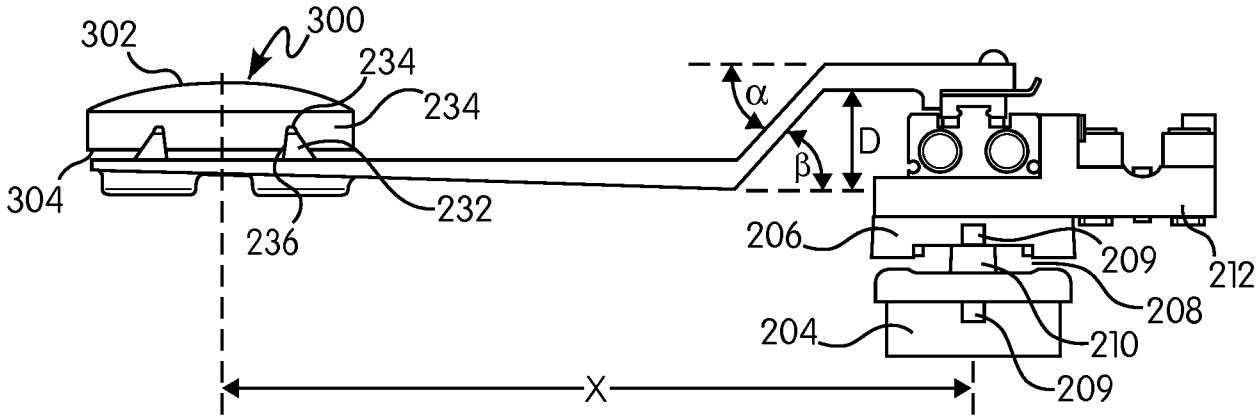

FIG. 4

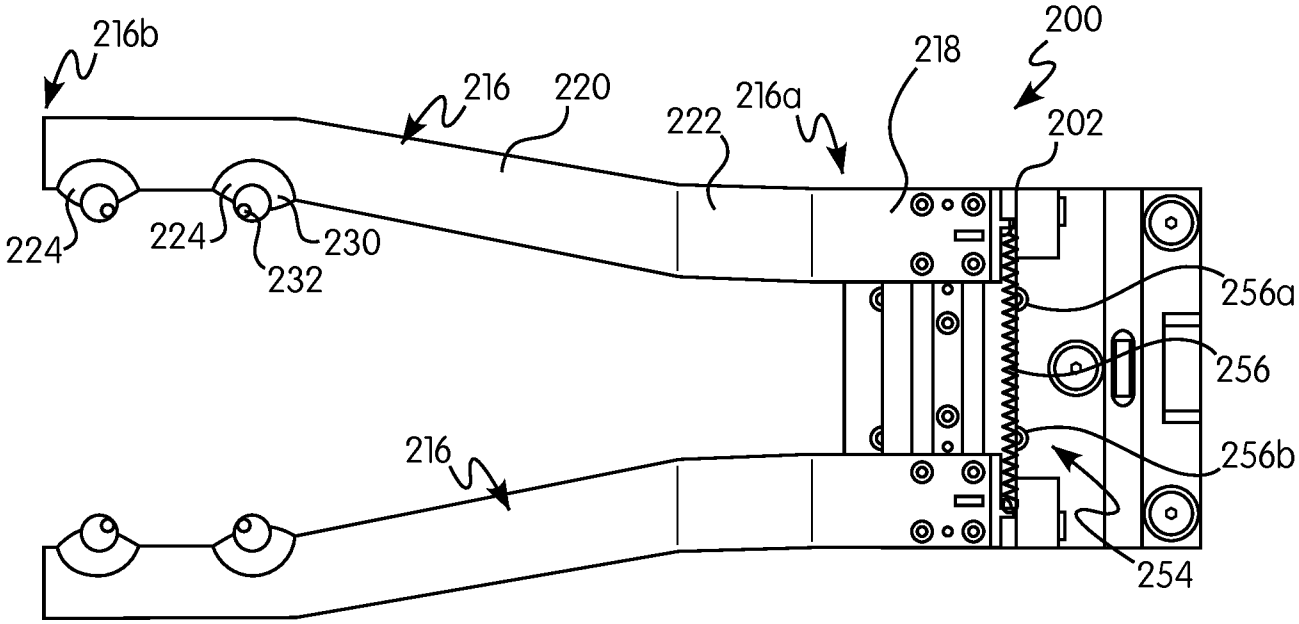

FIG. 5

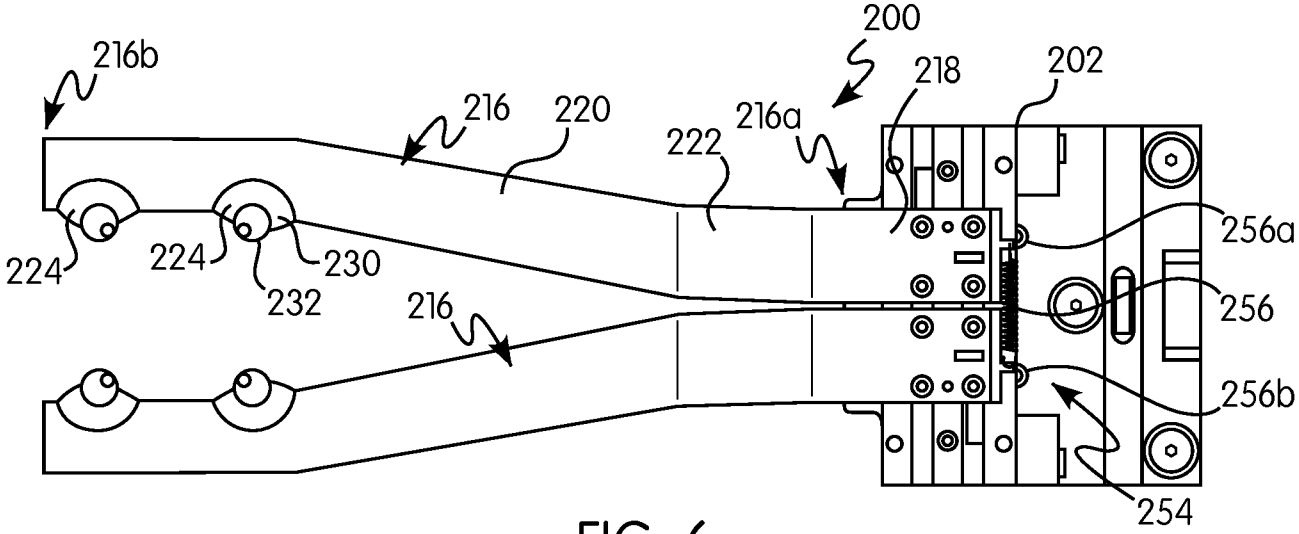

FIG. 6

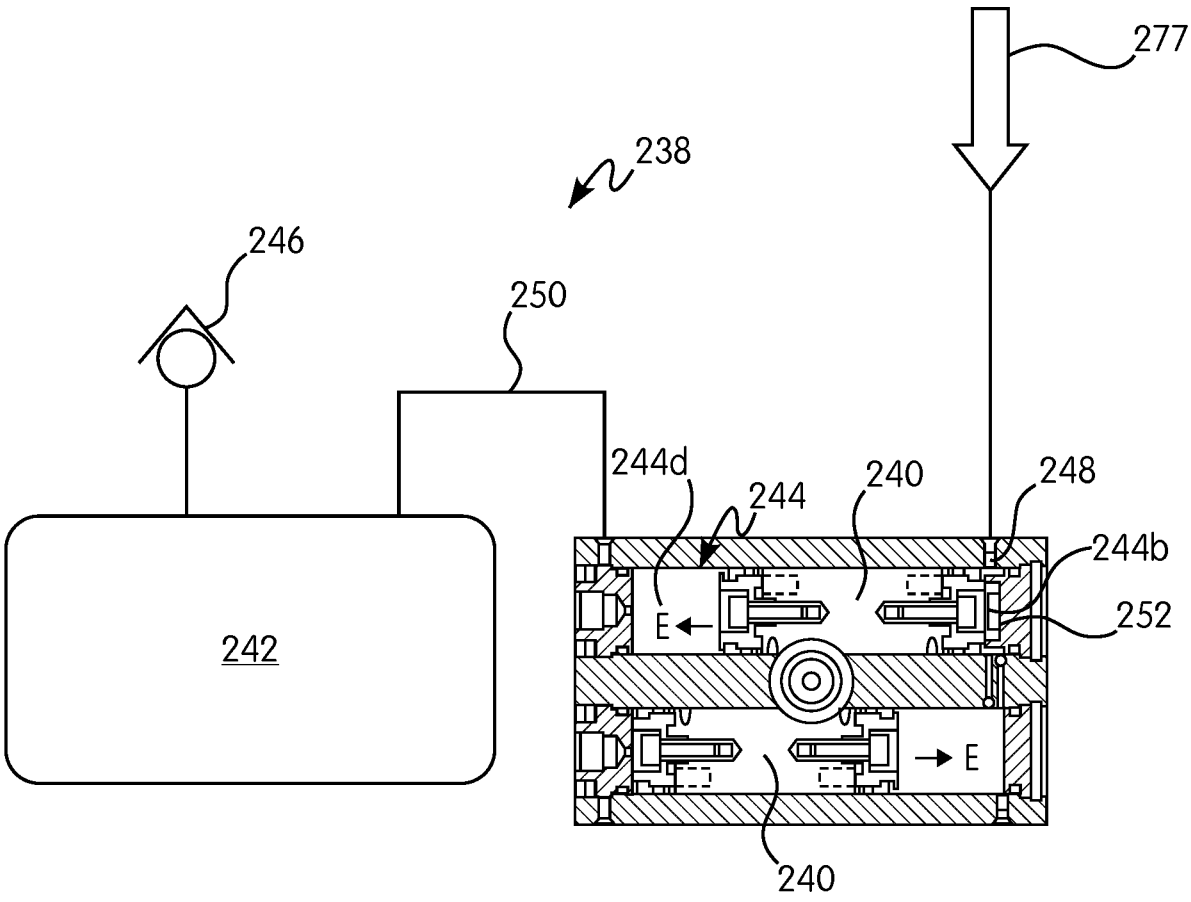

FIG. 7

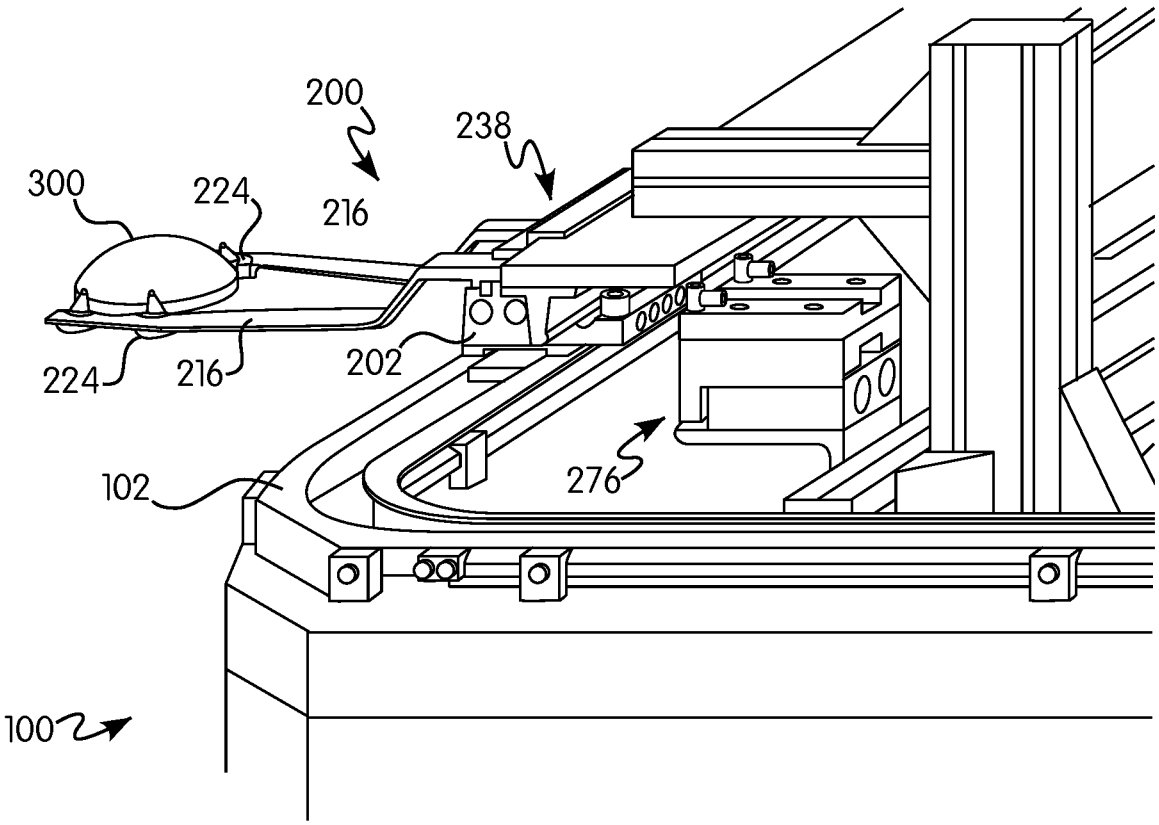
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FIG. 8

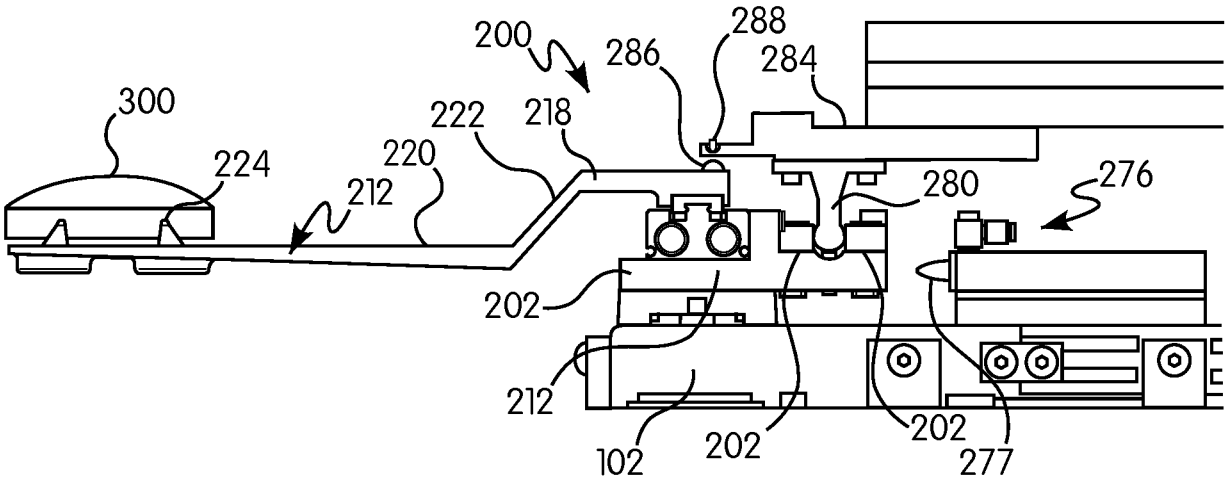
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FIG. 9

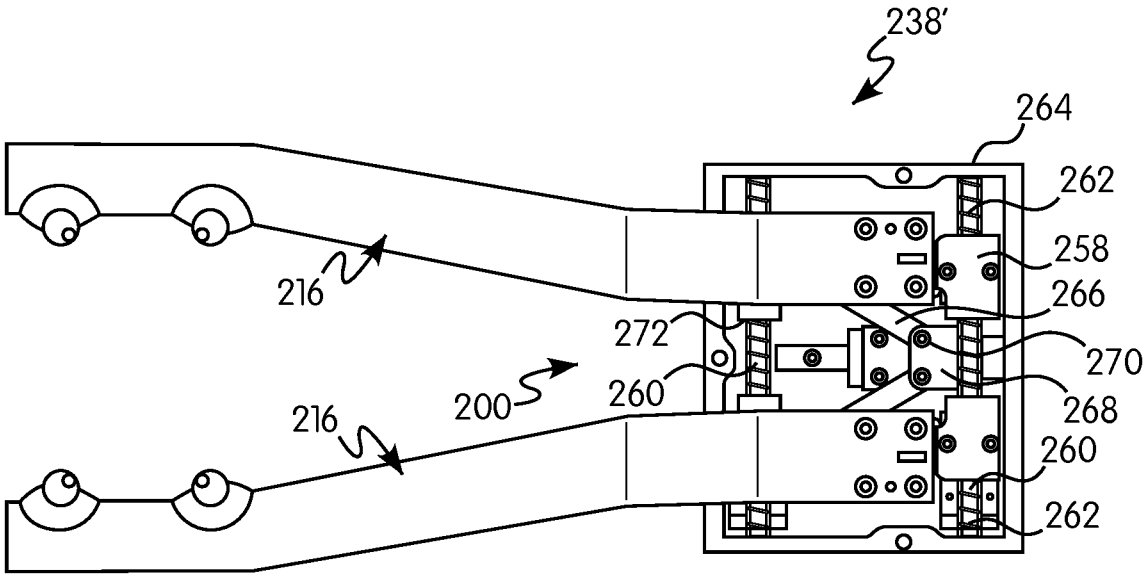
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FIG. 10

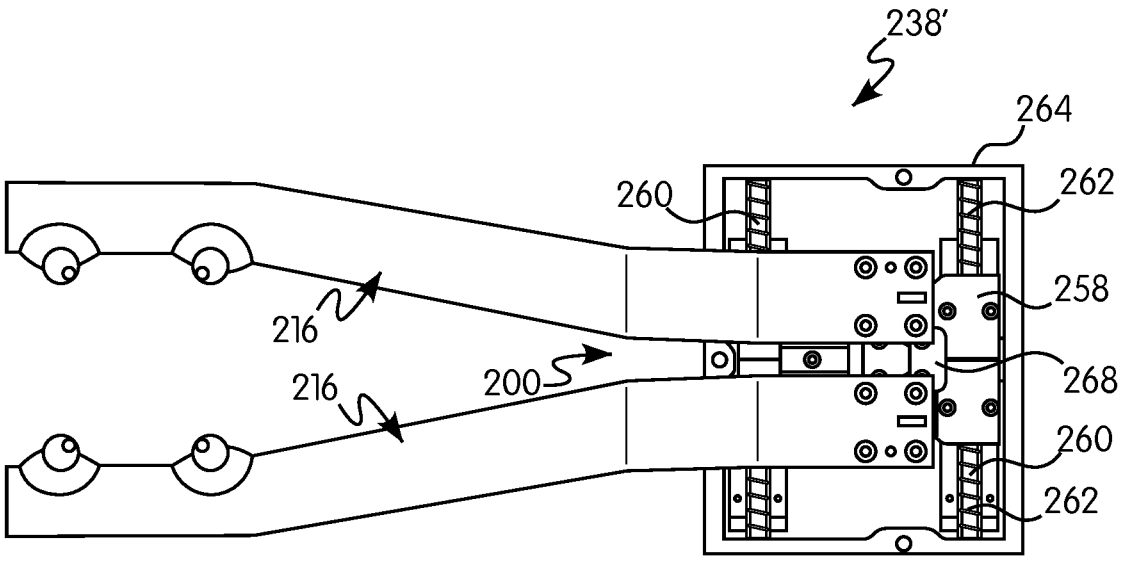
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FIG. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/ EP2018/057906

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29D11/00 B65G47/90
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B65G B29D B25J B25B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 747 737 A (BROOKE A) 24 July 1973 (1973-07-24)	1,5,6, 9-14
A	abstract figures 1,8 column 3, lines 11-30 column 3, lines 31-37 column 4, lines 27-41	2-4

X	EP 0 989 060 A2 (OMORI MACHINERY [JP]) 29 March 2000 (2000-03-29)	1-5,9-14
A	abstract figures 2,6,7,8b paragraphs [0011], [0013], [0032] - [0035], [0038] - [0039]	6

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[X] Further documents are listed in the continuation of Box C.

[X] 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) orwhich 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
23 January 2019	08/02/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Heckmann, Paul

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2018/057906

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

1-14

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 203 404 A (FILTRONA INSTR & AUTOMATION) 19 October 1988 (1988-10-19)	1-4,9-14
A	abstract figures 1-4,6-9 page 9 - page 10	5,6

X	US 2010/151069 A1 (NG KHENG JOO [FR] ET AL) 17 June 2010 (2010-06-17)	1,5,6, 9-14
A	abstract figures 2,8-14 paragraphs [0011] - [0118], [0120], [0137] - [0140], [0168] - [1174], [0214] - [0217], [0284] - [0285]	2-4

X	US 2012/241407 A1 (FAHLDIECK ANDREAS [DE]) 27 September 2012 (2012-09-27)	1,5,6, 9-14
A	abstract figures 1-7 paragraphs [0032] - [0033], [0036], [0037], [0041], [0049], [0050]	2-4

X	US 2006/070850 A1 (HARTNESS THOMAS P [US] ET AL) 6 April 2006 (2006-04-06)	1,5,9-14
A	abstract figures 3-9 paragraphs [0041], [0042], [0054], [0055], [0061] - [0064]	2-4,6

X	US 5 893 700 A (KRONSEDER HERMANN [DE]) 13 April 1999 (1999-04-13)	1,5,9-14
A	abstract figures 1,2 columns 3-4	2-4,6

A	US 5 201 501 A (FASSLER GEORGES [FR]) 13 April 1993 (1993-04-13) abstract figures 1-3	1-6,9-14

A	WO 96/28271 A1 (CHRISTENSEN JAN DALL [DK]; DEICHMANN ULRICH [DK]) 19 September 1996 (1996-09-19) abstract figures 1-3	1-6,9-14

X	US 2014/030048 A1 (KOSUGE RYUICHI [JP] ET AL) 30 January 2014 (2014-01-30)	1,5-14
A	abstract figures 8-12 paragraphs [0097] - [0102], [0108]	2-4

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International application No
PCT/EP2018/057906

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 2011 0105572 A (TOKYO ELECTRON LTD [JP]; WINS LTD [JP]) 27 September 2011 (2011-09-27) abstract figures 2-4 paragraphs [0029], [0030]	7,8
A	US 2013/140839 A1 (QUINN DARAGH PAUL [AU] ET AL) 6 June 2013 (2013-06-06) abstract figures 4a,4b paragraph [0062]	7,8
A	CN 103 659 809 A (UNIV GUANGXI) 26 March 2014 (2014-03-26) abstract figures 1,2	7,8

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/ EP2018/057906

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		US 2014030048 A1	30-01-2014
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2018/057906

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		WO 2013075033 A1	23-05-2013
CN 103659809 A	26-03-2014	NONE	

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 9-14

An article transport vehicle wherein the closure mechanism comprises an actuator, a first chamber on a first side of the actuator, and a second chamber on a second side of the actuator.

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2. claims: 7, 8

An article transport vehicle wherein the second end of each gripping arms has a pair of projections protruding inwardly from an inward lateral surface and upwardly from an upper surface of each gripping arm.

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3. claim: 15

An article transport vehicle wherein the carrier base comprises a magnetic flux source.
