United States Patent Application Publication	20250259872
Kind Code	A1
Publication Date	August 14, 2025
Inventor(s)	THANU; Rajkumar et al.

SWAPPER FOR A CLUSTER TOOL

Abstract

In one embodiment, a swapper for a cluster tool includes: a base, a pulley system, and first and second arms. The base may include an interior chamber. The base may be rotatable about a central axis. The pulley system may be at least partially disposed in the interior chamber. The pulley system may include a multi-level central pulley, first and second elbow pulleys, and first and second belts. The base may be rotatable relative to the multi-level central pulley. The first and second elbow pulleys may be rotatable about respective first and second elbow axes. Each belt may loop around a respective level of the multi-level central pulley and the corresponding elbow pulley. Each arm may be rotationally coupled to the respective elbow pulley such that rotation of the elbow pulley rotates the arm about the corresponding elbow axis.

Inventors: **THANU; Rajkumar (Santa Clara, CA), HUDGENS; Jeffrey C. (San Francisco, CA)**

Applicant: **Applied Materials, Inc.** (Santa Clara, CA)

Family ID: **96660021**

Appl. No.: **19/036301**

Filed: **January 24, 2025**

Related U.S. Application Data

us-provisional-application US 63552628 20240212

Publication Classification

Int. Cl.: **H01L21/677** (20060101); **B65G49/07** (20060101); **H01L21/67** (20060101); **H01L21/687** (20060101)

U.S. Cl.:

CPC **H01L21/67706** (20130101); **B65G49/07** (20130101); **H01L21/67201** (20130101); **H01L21/68707** (20130101); B65G2201/0297 (20130101)

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application claims priority to and the benefit of U.S. Provisional Patent Application No. 63/552,628 entitled “A SWAPPER FOR A CLUSTER TOOL” filed Feb. 12, 2024. The aforementioned application is incorporated by reference herein.

BACKGROUND
Field
[0002] Embodiments of the present disclosure generally relate to the linear transport of substrates, such as semiconductor substrates, in a cluster tool.
Description of the Related Art
[0003] Cluster tools are used in the manufacturing of semiconductor devices on substrates. Cluster tools have robotic mechanisms that are used to convey substrates between different chambers within the cluster tool. A substrate is placed in a load lock of the cluster tool and then may be transferred between multiple robotic mechanisms before being placed into a processing chamber that deposits or otherwise forms a layer or feature on the surface of the substrate. Additionally, these robotic mechanisms are operated by different motors.
[0004] There is a need in the art for an improved swapper robot to directly transfer a substrate from a load lock to a processing chamber.
SUMMARY
[0005] In one embodiment, a swapper for a cluster tool comprises a base, a pulley system, a first arm, and a second arm. The base including an interior chamber, wherein the base is rotatable about a central axis. The pulley system is at least partially disposed in the interior chamber. The pulley system includes a multi-level central pulley, a first elbow pulley, a second elbow pulley, a first belt, and a second belt. The base is rotatable relative to the multi-level central pulley. The first elbow pulley rotatable about a first elbow axis. The second elbow pulley rotatable about a second elbow axis. The first belt looping around a first level of the multi-level central pulley and the first elbow pulley. The second belt looping around a second level of the multi-level central pulley and the second elbow pulley. The first arm is rotationally coupled to the first elbow pulley such that rotation of the first elbow pulley rotates the first arm about the first elbow axis. The second arm is rotationally coupled to the second elbow pulley such that rotation of the second elbow pulley rotates the second arm about the second elbow axis.
[0006] In one embodiment, a swapper for a cluster tool comprises a base, a pulley system, a first arm, and a second arm. The base including an interior chamber, wherein the base is rotatable about a central axis. The pulley system is at least partially disposed in the interior chamber. The pulley system includes a multi-level central pulley, a multi-level first elbow pulley, a multi-level second elbow pulley, a first band, a second band, a third band, and a fourth band. The base is rotatable relative to the multi-level central pulley. The multi-level first elbow pulley is rotatable about a first elbow axis. The multi-level second elbow pulley is rotatable about a second elbow axis. A first end of the first band is anchored to a first level of the multi-level central pulley and a second end of the first band is anchored to a first level of the first multi-level elbow pulley. A first end of the second band is anchored to the first level of the multi-level central pulley and a second end of the second band is anchored to a first level of the second multi-level elbow pulley. A first end of the third band is anchored to a second level of the multi-level central pulley and a second end of the third band is anchored to a second level of the first multi-level elbow pulley. A first end of the fourth band is

anchored to the second level of the multi-level central pulley and a second end of the fourth band is anchored to a second level of the second multi-level elbow pulley. The first arm is rotationally coupled to the first multi-leveled elbow pulley such that rotation of the first multi-leveled elbow pulley rotates the first arm about the first elbow axis. The second arm is rotationally coupled to the second multi-leveled elbow pulley such that rotation of the second multi-leveled elbow pulley rotates the second arm about the second elbow axis.

[0007] In one embodiment, a swapper assembly for a cluster tool comprises a housing and a swapper. The housing includes a first opening and a second opening. The swapper includes a base, a first arm, and a second arm. The base is rotatable relative to the housing about a central axis. The first arm is rotationally coupled to the base, wherein the first arm rotates relative to the base about a first elbow axis from a first retracted position to a first extended position, wherein the first arm is partially disposed in the first opening in the first extended position and the first elbow axis is disposed in the housing in the first extended position. The second arm is rotationally coupled to the base, wherein the second arm rotates relative to the base about a second elbow axis from a second retracted position to a second extended position, wherein the second arm is partially disposed in the second opening in the second extended position and the second elbow axis is disposed in the housing in the second extended position.

[0008] In one embodiment, a swapper for a cluster tool comprises a base, a first base pulley system, a second base pulley system, a first link, a second link, a first arm, and a second arm. The base including an interior chamber, wherein the base is rotatable about a central axis. The first base pulley system is at least partially disposed in the interior chamber of the base. The first base pulley system includes a first multi-level central pulley, a multi-level first elbow pulley, a multi-level second elbow pulley, a first band, a second band, a third band, and a fourth band. The base is rotatable relative to the first multi-level central pulley. The multi-level first elbow pulley is rotatable about a first elbow axis. The multi-level second elbow pulley is rotatable about a second elbow axis. A first end of the first band is anchored to a first level of the first multi-level central pulley and a second end of the first band is anchored to a first level of the first multi-level elbow pulley. A first end of the second band is anchored to a second level of the first multi-level central pulley and a second end of the second band is anchored to a second level of the first multi-level elbow pulley, wherein the first band crosses above the second band. A first end of the third band is anchored to the first level of the first multi-level central pulley and a second end of the third band is anchored to a first level of the second multi-level elbow pulley. A first end of the fourth band is anchored to the second level of the first multi-level central pulley and a second end of the fourth band is anchored to a second level of the second multi-level elbow pulley, wherein the third band crosses above the fourth band. The second base pulley system is at least partially disposed in the interior chamber of the base. The second base pulley system includes a second multi-level central pulley, a first pulley, a second pulley, a first belt, and a second belt. The second multi-level central pulley is rotatable relative to the first multi-level central pulley about the central axis. The first pulley is rotatable about the first elbow axis. The second pulley is rotatable about the second elbow axis. The first belt is looped around a first level of the second multi-level central pulley and the first pulley. The second belt is looped around a second level of the second multi-level central pulley and the second pulley. The first link is rotatably attached to the first elbow pulley and including a first link pulley system at least partially disposed in a first chamber of the first link. The first link pulley system comprises a first link pulley, a second link pulley, a first belt. The first link pulley is rotationally coupled to the first pulley such that rotation of the first pulley rotates the first link pulley about the first elbow axis. The second link pulley is rotatable about a first arm axis. The first belt is looped around the first link pulley and the second link pulley. The second link attached to the second elbow pulley including a second link pulley system at least partially disposed in a second chamber of the second link. The second link pulley system comprises a third link pulley, a fourth link pulley, and a second belt. The third link pulley is rotationally coupled to the second pulley such that rotation of the second pulley rotates the second link pulley about the second elbow axis. The fourth link pulley is rotatable about a second arm axis. The second belt looped around the third link pulley and the fourth link pulley. The first arm is rotationally coupled to the second link pulley such that rotation of the second link pulley rotates the first arm about the first arm axis. The second arm rotationally coupled to the fourth link pulley such that rotation of the fourth link pulley rotates the second arm about the second arm axis.

[0009] In one embodiment, a method of operating a swapper includes moving a first arm of the swapper from a first extended position to a first partially retracted position by rotating a base of a swapper about a central axis in a first direction while rotating a first link coupled to the base in the first direction and rotating the first arm coupled to the first link in a second direction. The method further includes moving the first arm of the swapper to a second partially retracted position from the first partially retracted position by rotating the base in the first direction while rotating the first link in the first direction and rotating the first arm in the second direction. The method further includes moving the first arm of the swapper to a retracted position from the second partially retracted position by rotating the base in the second direction while rotation the first link in the second direction and rotating the first arm in the second direction.

[0010] In one embodiment, an in-line tensioner comprises a block and a biasing element. The block includes a channel, a first block opening, and a second block opening. The biasing element is disposable in the channel. The biasing element includes a first portion including a slot, a second portion including a block fastener opening, and a third portion disposed between the first portion and the second portion. The third portion includes a plurality of spring slots. The third portion is configured to bias the first portion towards the second portion.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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 of the disclosure and are therefore not to be considered limiting of its scope, as the disclosure may admit to other equally effective embodiments.

[0012] FIG. **1**A illustrates a schematic plan view of an exemplary cluster tool, according to embodiments described herein.

[0013] FIG. **1**B is a schematic partial cross-sectional view of a swapper assembly, according to embodiments described herein.

[0014] FIG. **1**C is a partial exploded view of a swapper, according to embodiments herein.

[0015] FIG. **2**A illustrates a schematic plan view of an exemplary cluster tool, according to embodiments described herein.

[0016] FIG. **2**B is a schematic partial cross-sectional view of a swapper assembly, according to embodiments described herein.

[0017] FIG. **2**C is a partial exploded view of a swapper, according to embodiments herein.

[0018] FIG. **3**A illustrates a schematic plan view of an exemplary cluster tool, according to embodiments described herein.

[0019] FIG. **3**B illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **3**A showing the arms of the swapper in an extended position, according to embodiments described herein.

[0020] FIG. **3**C illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **3**A showing the arms of the swapper in a partially retracted position, according to

embodiments described herein.
[0021] FIG. **3**D illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **3**A showing the arms of the swapper in a retracted position, according to embodiments described herein.
[0022] FIG. **3**E illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **3**A showing the arms of the swapper in a partially extended position, according to embodiments described herein.
[0023] FIG. **3**F illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **3**A showing the arms of the swapper in an extended position, according to embodiments described herein.
[0024] FIG. **4**A illustrates a schematic plan view of an exemplary cluster tool, according to embodiments described herein.
[0025] FIG. **4**B is a partial exploded view of a swapper, according to embodiments herein.
[0026] FIG. **4**C illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in a first partially retracted position, according to embodiments described herein.
[0027] FIG. **4**D illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in a second partially retracted position, according to embodiments described herein.
[0028] FIG. **4**E illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in a retracted position, according to embodiments described herein.
[0029] FIG. **4**F illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in a first partially extended position, according to embodiments described herein.
[0030] FIG. **4**G illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in a second partially extended position, according to embodiments described herein.
[0031] FIG. **4**H illustrates a partial schematic plan view of the exemplary cluster tool shown in FIG. **4**A showing the arms of the swapper in an extended position, according to embodiments described herein.
[0032] FIG. **5** illustrates a partial exploded view of a belt system to show an exemplary in-line tensioner, according to embodiments described herein.
[0033] 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

[0034] The present disclosure generally provides an apparatus and method for processing substrates using a multi-chamber processing system (e.g., a cluster tool) adapted to process substrates. A cluster tool is a system comprising multiple chambers which perform various functions in the electronic device fabrication process. The cluster tool includes at least two swapping mechanisms operated by the same motor assembly to transfer substrates between two chambers within the cluster tool.
[0035] FIG. **1**A illustrates a schematic plan view of a cluster tool **100**. The cluster tool **100** includes a factory interface **102**, two substrate processing chambers **110**, a substrate swapper assembly **120**, two load locks **170**, and a controller **190**. The load locks **170** and processing chambers **110** are in pairs, with each pair having one load lock **170** opposing a corresponding processing chamber **110**. The substrate swapper assembly **120** is located between the processing chambers **110** and the load locks **170**. The substrate swapper assembly **120** includes a swapper **130** for each pair of the

processing chambers **110** and load locks **170**. Each swapper **130** is used to swap the substrates **105** between the processing chamber **110** and load lock **170**. The cluster tool **100** may also include a vacuum assembly **107** that is used to create and/or maintain a pressure within the cluster tool **100**, such as the pressure within each processing chamber **110**, the swapper assembly **120**, and each load lock **170**.

[0036] The factory interface **102** may be coupled to one or more front opening unified pods (FOUPs) **103**. FOUPs **103** may each be a container having a stationary cassette therein for holding multiple substrates. FOUPs **103** may each have a front opening interface configured to be used with factory interface **102**. Factory interface **102** may have a buffer chamber (not shown) and one or more robot assemblies (not shown) configured to transfer substrates via linear, rotational, and/or vertical movement between FOUPs **103** and the load locks **170**.

[0037] The processing chambers **110** include a substrate support **112** (e.g., pedestal, platen) and a processing kit and source assembly configured to process the substrate **105** within the processing chamber **110**. The processing chambers **110** may perform any number of processes such as preclean, PVD, CVD, ALD, decoupled plasma nitridation (DPN), rapid thermal processing (RTP), and etching. In one embodiment, the processing sequence is adapted to form a high-K capacitor structure, where processing chambers **110** may be a DPN chamber, a CVD chamber capable of depositing poly-silicon, and/or a MCVD chamber capable of depositing titanium, tungsten, tantalum, platinum, or ruthenium. The substrate support **112** may include one or more lift pins to lift and lower the substrate **105** relative to the substrate support **112**, such as using the lift pins to transfer the substrate **105** to or from the swapper **130**. In some embodiments, a slit valve **114** is located between the processing chamber **110** and the swapper assembly **120**. When the slit valve **114** is in an open position, the swapper **130** is allowed to enter a tunnel **113** of the processing chamber **110**. When the slit valve **114** is in the closed position, the processing chamber **110** is isolated from the swapper assembly **120**. In some embodiments, the slit valve **114** is omitted.

[0038] Each load lock **170** may have a first slit valve **171** and a second slit valve **172**. When the first slit valve **171** is open, a substrate **105** can be transferred from the factory interface **102** and to support members, such as lift pins, positioned in the load lock **170**. When the first slit valve **171** is closed, the interior of the load lock **170** is isolated from the factory interface **102**. Thus, the load locks **170** provide a vacuum interface between the factory interface **102** (e.g., front-end environment) and the remainder the cluster tool **100**. When the second slit valve **172** is open, the swapper **130** is allowed to enter an opening **173** in the load lock **170** where the substrate **105** is then transferred to the swapper **130**. The second slit valve **172** may be closed to block the opening **173**. When the second slit valve **172** is closed, the interior of the load lock **170** is isolated from the swapper assembly **120** and the processing chambers **110**. In some embodiments, there is only one load lock **170** that is configured to receive each swapper **130**.

[0039] FIGS. **1**A and **1**B illustrate the swapper assembly **120**, with FIG. **1**B showing a schematic partial cross-sectional view of the swapper assembly **120**. The swapper assembly **120** additionally includes a housing **122** and one or more motor assemblies **160**. The housing **122** defines an internal swapper chamber **123**. The swappers **130** are disposed in the swapper chamber **123**, and the substrates **105** pass through the swapper chamber **123** between the load locks **170** and the processing chamber **110**. Each swapper **130** is operated by a motor assembly **160** that is configured to move the swapper **130** between a retracted position and an extended position. In some embodiments, a wall of the housing **122** bifurcates the swapper chamber **123** such that each swapper **130** is isolated from the other.

[0040] Each swapper **130** includes a base **131**, an arm assembly **140**, and a pulley system **150**. The base **131** includes an interior chamber **134** partially defined by the walls **135** of the base **131**. The pulley system **150** is at least partially disposed within the interior chamber **134** of the base **131**. The arm assembly **140** is supported by the base **131**. The base **131** may be connected to a first shaft **162** of the motor assembly **160**. A motor **161** of the motor assembly **160** rotates the first shaft **162** about a central axis **132** of the swapper **130**, thereby rotating the base **131** about the central axis **132**. In some embodiments, one or more seals may be disposed around the first shaft **162** to seal the swapper chamber **123** from the outside environment while facilitating the rotation of the base **131** relative to the housing **122**.

[0041] The arm assembly **140** includes a first arm **141** (e.g., left arm) and a second arm **142** (e.g., right arm) that are rotated by the pulley system **150**. The arms **141**, **142** are moveable to extended positions where each arm **141**, **142** is located within either the load lock **170** or the processing chamber **110** to convey a substrate **105** disposed on the arm **141**, **142**. FIG. **1**A shows the arms **141**, **142** of the swapper **130** on the right-hand side of the figure in a first extended position while the arms **141**, **142** of the swapper **130** on the left-hand side of the figure are shown in a second extended position. As will be explained below, the difference in the first extended position and the second extended position allows for the swapper **130** to center the substrate **105** within the processing chamber **110**. FIG. **1**A shows the first arm **141** positioned within the processing chamber **110** above the substrate support **112** while the second arm **142** is shown positioned within the load lock **170**. The arms **141**, **142** are moved to swap positions, such that the first arm **141** is moved to into the load lock **170** while the second arm **142** is moved into the processing chamber **110**. The arms **141**, **142** may also be moved to a retracted position (FIG. **1**B) where the arms **141**, **142** overlap one another. The arms **141**, **142** may be retracted while the arms **141**, **142** are swapped between the load lock **170** and the processing chamber **110**. The arms **141**, **142** may also be retracted while a substrate **105**, placed into the processing chamber **110**, is processed.

[0042] The arms **141**, **142** (e.g., end effectors) each include a support **144** with a support surface **145** as shown in FIG. **1**C. As shown in FIG. **1**A, the support **144** may have a fork shape or other desirable shape to support the substrate **105**. The substrate **105** is placed into engagement with the support surface **145** of the support **144**. The support **144** carries the substrate **105** disposed thereon as the swapper **130** moves the substrate **105** between the load lock **170** and the processing chamber **110**. As shown in FIG. **1**B, the support **144** of the first arm **141** and second arm **142** are located at different heights such that one arm can pass underneath the other arm without the substrate **105** on the lower arm contacting the upper arm. As shown, the first arm **141** is located at a height above the base **131** that is lower than the second arm **142**. A clearance is present between the support surface **145** of the support **144** of the first arm **141** and the underside of the second arm **142**. This clearance is sized to allow the substrate **105** to pass underneath the second arm **142** without contacting the second arm **142**.

[0043] As shown in FIG. **1**A, the base **131** partially extends into the opening **173** in the load lock **170** and partially extends into the tunnel **113** of the processing chamber **110**. As shown in FIG. **1**B, the swapper **130** has a first height H**1** that extends from the underside of the base **131** to the upper side of the second arm **142**. This first height H**1** is less than the height of the opening of the tunnel **113** of the processing chamber **110** and the height of the opening **173** in the load lock **170**. In other words, the swapper **130** is sized to allow the base **131** and arm assembly **140** to enter the opening **173** and tunnel **113** without contact. A second height H**2** is shown extending from the underside of the second arm **142** to the top surface of the first arm **141**. In some embodiments, the tunnel **113** may include an opening formed in the housing **122** of the swapper assembly **120**. Additionally, the opening **173** may include an opening formed in the housing **122** of the swapper assembly **120**. In other words, the swapper assembly **120** may have a first opening in the housing **122** aligned with the tunnel **113** and a second opening in the housing **122** aligned with the opening **173**.

[0044] The opening **173** and the tunnel **113** each have a height that exceeds first height H**1** such that the base **131** and arms **141**, **142** may pass through without contacting a surface of the opening **173** or tunnel **113**. For example, the opening **173** and tunnel **113** may have a height that is at least 50 mm, such as 55 mm, such as 60 mm, such as 70 mm. In some embodiments, the base **131** may have a height between 20 mm and 30 mm, such as about 20 mm, such as about 25 mm, such about 30 mm. The distance from the upper surface of the base **131** to the upper surface of the first arm

141 may also be between 20 mm and 30 mm, such as about 20 mm, such as about 25 mm, such about 30 mm.

[0045] As shown in FIGS. **1**A and **1**B, the support **144** of each arm **141**, **142** has center point **147** that may or may not be located on the support surface **145** depending on the shape of the support **144**. The center point **147** is the location of the support **144** that will be aligned with the center of the substrate **105** if the substrate **105** is properly centered on the support surface **145**.

[0046] FIG. **1**A shows a substrate **105** placed on the support **144** of each arm **141**, **142**. A portion of each arm **141**, **142** is shown in dashed to illustrate that the substrate **105** is supported on the corresponding arm **141**, **142**. The center point **147** of each arm **141**, **142** will follow the trajectory **146** as the motor assembly **160** operates the swapper **130** to move the arms **141**, **142**. As shown in FIG. **1**A, the trajectory **146** (shown as a line) is a substantially linear path that extends from the center point of the substrate support **112**, over the central axis **132** of the swapper **130**, to a center point of the load lock **170**. In other words, the center point **147** moves linearly as the first arm **141** and second arm **142** swap positions. The substrate **105** disposed on the support **144** of each arm **141**, **142** similarly moves in a linear fashion. Thus, the swapper **130** is used to move the substrates **105** in a linear trajectory between the load lock **170** and processing chamber **110**, and vice versa. The arms **141**, **142** move the substrate **105** disposed thereon along parallel linear trajectories that are separated by a distance since each arm **141**, **142** is located at a different height. And, as shown in FIG. **1**A, each pair of processing chambers **110** and load locks **170** are positioned opposing each other across the swapper assembly **120** such that the linear trajectory of the substrates **105** moved by one swapper **130** is parallel to the linear trajectory of the substrates **105** moved by the other swapper **130**.

[0047] FIGS. **1**B and **1**C show the pulley system **150**. FIG. **1**C illustrates a partial exploded view of the swapper **130** to show the interconnection of the pulley system **150** with other select components of the swapper **130**. The pulley system **150** includes a central pulley **151**, a first belt **153**, a second belt **154**, a first elbow pulley **156***a*, and a second elbow pulley **156***b*. The first arm **141** is attached to the first elbow pulley **156***a* and the second arm **142** is attached to the second elbow pulley **156***b*. In some embodiments, the central pulley **151** is in a fixed position. For example, the central pulley **151** may be fixed on a second shaft **163** that extends into the interior chamber **134** through an opening in the walls **135** of the base **131** and through an opening of the first shaft **162**. The motor assembly **160** may include one or more bearing elements to facilitate the rotation of the base **131** and the first shaft **162** relative to the second shaft **163**.

[0048] The central pulley **151** is shown as a multi-level pulley, in that the central pulley **151** accommodates both the first belt **153** and the second belt **154**. Each level of the central pulley **151** may include a groove to engage the respective belt **153**, **154**. The elbow pulleys **156***a*,*b* are shown as single-level pulleys to guide a respective belt **153**, **154**. As shown, the second belt **154** is positioned above the first belt **153**. The first belt **153** is wrapped around the first level of the central pulley **151** and the first elbow pulley **156***a* while second belt **154** is wrapped around the second level of the central pulley **151** and the second elbow pulley **156***b*.

[0049] In some embodiments, and as shown in FIGS. **1**B and **1**C, the first belt **153** and second belt **154** may each be at a desired tension during operation of the swapper **130** to facilitate the movement of the arms **141**, **142**. In some embodiments, the first belt **153** and second belt **154** each have an in-line tensioner **155** to maintain the tension of the belt. The in-line tensioner **155** is fixed to both ends of the corresponding belt **153**, **154**. The in-line tensioner **155** may be adjusted to apply a desired tension the corresponding belt **153**, **154**. In some embodiments, the corresponding belt **153**, **154** may be stretched to a desired tension and then each end of the corresponding belt **153**, **154** is fastened to the tensioner to hold the belt in tension. In some embodiments, the in-line tensioner **155** described herein may be the in-line tensioner **510** shown in FIG. **5**. In some embodiments, the first belt **153** and second belt **154** each have a width (extending in the direction of first height H**1**) that is about 8 mm to fit within the interior chamber **134**. Additionally, the first and second belts **153**, **154** may each also have a thickness of at least 0.08 mm to max stress applied to the belt, which includes the torque working load, pre-load of the tensioners **155**, and the bending. In some embodiments, the belts **153**, **154** have a thickness between 0.08 mm to 0.12 mm, such having a thickness of 0.08 mm, such having a thickness of 0.09 mm, such having a thickness of 0.1 mm, such having a thickness of 0.11 mm, such having a thickness of 0.12 mm.

[0050] Each arm **141**, **142** has a shaft **157**. The shaft **157** of the first arm **141** is attached to the first elbow pulley **156***a* and the shaft **157** of the second arm **142** is attached to the second elbow pulley **156***b*. For example, the shaft **157** of each arm may be attached to an outer race of the respective elbow pulley **156***a,b*. The first elbow pulley **156***a*, and thus the first arm **141**, rotates about a first elbow axis **149***a*. The second elbow pulley **156***b*, and thus the second arm **142**, rotates about a second elbow axis **149***b*.

[0051] Each of the elbow pulleys **156***a,b* may include bearing elements **158** to facilitate the rotation of the shaft **157**, and thus the respective arm **141**, **142**, relative to the base **131**. For example, an inner race of each elbow pulley **156***a,b* may be mounted on a mounting shaft **136** of the base **131**. An outer race is engaged with the respective belt **153**, **154**. The bearing elements **158** allow an outer race of each pulley **156***a,b* to rotate relative to the inner race.

[0052] FIG. **1**B shows the motor assembly **160** connected with one swapper **130**, which is representative of the connection of the motor assembly **160** with the other swapper **130** shown in FIG. **1**A. The motor assembly **160** extends through the lower wall of the housing **122**. The motor assembly **160** includes a motor **161** that rotates first shaft **162**. The motor assembly **160** may include seals between components to prevent in inflow of gases into the swapper chamber **123** through the motor assembly **160**.

[0053] As the base **131** rotates, the elbow pulleys **156***a,b* rotate (e.g., orbit) around the central pulley **151** which does not rotate. The first belt **153** causes the first elbow pulley **156***a* to rotate as the base **131** rotates relative to the central pulley **151**, thereby rotating the first arm **141** about the first elbow axis **149***a*. Similarly, the second belt **154** causes the second elbow pulley **156***b* to rotate about as the base **131** moves relative to the central pulley **151**, thereby rotating the second arm **142** about the second elbow axis **149***b*.

[0054] The ratio of the central pulley **151** to each elbow pulley **156***a,b* is configured to achieve a desired shape and resolution of the path (e.g., linear movement) in which the substrate **105** is transferred between the load lock **170** and processing chamber **110**. In some embodiments, the central pulley **151** has diameter twice the diameter of the elbow pulleys **146***a,b* (e.g., 2:1 ratio) to achieve the linear trajectory **146**.

[0055] As shown in FIG. **1**B, a distance D**1** extends from the central axis **132** to each elbow axis **149***a,b*. In other words, each elbow pulley **146***a,b* is positioned on the base **131** at the same distance (shown as D**1**) from the central axis **132**. The distance between the center point **147** and respective elbow axis **149***a,b* of the first and second arm **141**, **142** is shown as D**2**. This distance D**2** is the same as distance D**1**. In some embodiments, the distances D**1** and D**2** may be selected based on the desired reach (e.g., distance between the central axis **132** and the center point **147** when the arms **141**, **142** are extended) of the swapper **130**.

[0056] In some operations of the cluster tool **100**, the substrate **105** may not be centered above the center point **147** of an arm **141**, **142**. In some embodiments, the distances D**1** and D**2** are selected to allow the swapper **130** to align the center of the substrate **105** within the processing chamber **110** and/or load lock **170**.

[0057] Referring back to FIG. **1**A, the swapper **130** on the right-hand side of the cluster tool **100** is shown in the first extended position. As shown, the central axis **132** and the elbow axes **149***a*, **149***b* are not aligned when the swapper **130** is in the first extended position. The first extended position of the arms **141**, **142** is the nominal reach of the swapper **130**. In other words, the center point **147** of the first and second arms **141**, **142** will either be aligned with the center of substrate support **112** or the center of the load lock **170** when in the first extended position. The nominal reach of the first

arm **141** is shown as nominal reach R**1**, which is representative of the nominal reach of the second arm **142**.
[0058] Referring to FIG. **1**A, the swapper **130** on the left-hand side of the cluster tool **100** is shown in the second extended position. As shown, the central axis **132** and the elbow axes **149***a*, **149***b* are aligned in the second extended position. The second extended position of the arms **141**, **142** is an overreach position that places the center point **147** of the respective arm **141**, **142** past the center of either the substrate support **112** or the load lock **170**. The distance D**1** and distance D**2** may be selected such that the arms **141**, **142** have an overreach sufficient to align an offset substrate **105** with either the center of the substrate support **112** or center of the load lock **170**. The overreach of the first arm **141** is shown as overreach R**2**, which is representative of the overreach of the second arm **142**. As shown in FIG. **1**A, there is a differential, shown as R**3**, between the nominal reach R**1** and overreach R**2**.
[0059] The arms **141**, **142** may be extended to one or more positions between the first extended position and second extended position, including the second position, to correct the offset of the substrate **105**. For example, the center point **147** moves along the trajectory **146** as the first arm **141** moves to one or more positions between the first position and the second position. A location center finder sensor ("LCF sensor") may determine an offset between the center of the substrate **105** and the center point **147** of an arm **141**, **142**. The controller **190** may use the offset of the substrate **105** to determine a position between the first extended position and the second extended position that will place the center of the substrate **105** in alignment with the center of the substrate support **112**. Thus, selecting a distance D**1** and D**2** that allows the arms **141**, **142** to overreach extends the trajectory **146** to allow the center of the substrate **105** to be aligned along the distance of differential reach R**3**.
[0060] In some embodiments, the pulley system **150** is configured to allow for the swappers **130** to make full 360 degree rotations about the central axis **132**. In some embodiments, the pulley system **150** may have limited rotation. For example, the pulley system **150** shown in FIGS. **1**B and **1**C allows for the base **131** to be rotated plus or minus 90 degrees about the central axis **132** from the retracted position (e.g., folded arms **141**, **142** shown in FIG. **1**B) to the second extended position shown in FIG. **1**A. The in-line tensioner **155** of the first belt **153** and second belt **154** is positioned to allow the 90 degrees of rotation to extend the arms **141**, **142** to the overreach position. The in-line tensioners **155**, however, limit the overall rotation of the swapper **130** about the central axis **132** to avoid engaging the tensioners **155** with either the central pulley **151** or the respective elbow pulley **156***a,b*.
[0061] The first belt **153** and second belt **154** may precess (e.g., creep) around the central pulley **151** and the respective elbow pulleys **156***a,b* after repeated cycles of operation of the swapper **130**. This belt precession can result in the arms **141**, **142** deviating from the desired motion, such as causing a deviation in the trajectory **146**. This belt precession can therefore interfere with aligning the center of the substrate **105** above the center of the processing chamber **110** and the load lock **170**. The LCF sensors may be used to monitor for a drift in the motion of the swapper **130** that indicates that the first belt **153** and second belt **154** have moved out of alignment with the central pulley **151** and the respective elbow pulley **156***a,b*. For example, the LCF sensor may detect that the center of the substrate **105** deviates from an expected position at one or more positons of the arms **141**, **142**, which indicates that the arms **141**, **142** are deviating from the desired motion. The swapper **130** is then serviced to adjust the alignment of the belts **153**, **154** to the desired alignment to correct the motion of the arms **141**, **142**.
[0062] In some embodiments, the cluster tool includes three or more pairs of load locks **170** and processing chambers **110**, and one swapper assembly **120** with a swapper **130** located between each pair of load locks **170** and processing chambers **110**. In some embodiments, the cluster tool can have one or more levels of the plan view shown in FIG. **1**A stacked on top of one another.
[0063] The controller **190** can be in communication with each motor assembly **160** to control the

position of the arms **141**, **142** of the swappers **130**. In some embodiments, both swappers **130** may be moved synchronously. The controller **190** may include a programmable central processing unit (CPU) which is operable with a memory (e.g., non-transitory computer readable medium and/or non-volatile memory) and support circuits. The support circuits are coupled to the CPU and includes cache, clock circuits, input/output subsystems, power supplies, and the like, and combinations thereof coupled to the various components of the cluster tool **100**, to facilitate control of the cluster tool **100**. For example, in one or more embodiments the CPU is one of any form of general purpose computer processor used in an industrial setting, such as a programmable logic controller (PLC), for controlling various polishing system components and sub-processors. The memory, coupled to the CPU, is non-transitory and is one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk drive, hard disk, or any other form of digital storage, local or remote.

[0064] Herein, the memory is in the form of a computer-readable storage media containing instructions (e.g., non-volatile memory), that when executed by the CPU, facilitates the operation of the cluster tool **100**. The instructions in the memory are in the form of a program product such as a program that implements the methods of the present disclosure (e.g., middleware application, equipment software application, etc.). The program code may conform to any one of a number of different programming languages. In one or more embodiments, the disclosure may be implemented as a program product stored on computer-readable storage media for use with a computer system. The program(s) of the program product define functions of the embodiments (including the methods and operations described herein).

[0065] Illustrative computer-readable storage media include, but are not limited to: (i) non-writable storage media (e.g., read-only memory devices within a computer such as CD-ROM disks readable by a CD-ROM drive, flash memory, ROM chips or any type of solid-state non-volatile semiconductor memory) on which information is permanently stored; and (ii) writable storage media (e.g., floppy disks within a diskette drive or hard-disk drive or any type of solid-state random-access semiconductor memory) on which alterable information is stored. Such computer-readable storage media, when carrying computer-readable instructions that direct the functions of the methods described herein, are embodiments of the present disclosure.

[0066] The various methods and operations disclosed herein may generally be implemented under the control of the CPU of the controller **190** by the CPU executing computer instruction code stored in the memory (or in memory of a particular processing chamber) as, e.g., a software routine. When the computer instruction code is executed by the CPU, the CPU controls the components of the cluster tool **100** to conduct operations in accordance with the various methods and operations described herein. In one or more embodiments, the memory (a non-transitory computer readable medium) includes instructions stored therein that, when executed, cause the methods and operations described herein to be conducted. The operations described herein can be stored in the memory in the form of computer readable logic.

[0067] FIG. **2**A illustrates a schematic plan view of a cluster tool **200**. The cluster tool **200** has similar components of cluster tool **100** as indicated by the reference signs without reciting the description of these components for brevity. As shown, the cluster tool **200** has a swapper assembly **220** substituted for the swapper assembly **120**. The swapper assembly **220** has similar components as the swapper assembly **120** as indicated by the reference signs without reciting the description of these components of the swapper assembly **120** for brevity. The swappers **230** of cluster tool **200** have a pulley system **250** (shown in FIGS. **2**B, **2**C) in place of pulley system **150**.

[0068] FIG. **2**B illustrates a schematic partial cross-sectional view of the swapper assembly **220** showing the arms **141**, **142** in a retracted position. FIG. **2**C illustrates a partial exploded view of the swapper **230** to show the interconnection of the pulley system **250** with other select components of the swapper **230**.

[0069] As shown, the pulley system **250** of the swapper **230** includes a central pulley **251**, a first elbow pulley **256***a*, a second elbow pulley **256***b*, a first band **261**, a second band **262**, a third band **263**, and a fourth band **264**. Each of the bands **261-264** may be tensioned at the desired tension to facilitate the operation of the swapper **230**. In some embodiments, each band **261-264** may each have an in-line tensioner **155**.

[0070] The central pulley **251** is mounted similarly to central pulley **151**, in that the central pulley **251** is fixed (e.g., stationary) and the base **131** is rotated relative to the central pulley **251** by the motor assembly **160**. The central pulley **251** is a multi-level pulley, in that a first end of the first band **261** and a first end of the second band **262** are anchored to a first level of the central pulley **251** and a first end of the third band **263** and a first end of the fourth band **264** are anchored to a second level of the central pulley **251**. In some embodiments, the bands **261-264** may be anchored to the central pulley **251** by an adhesive or a fastener. In some embodiments, the portion of bands **261-264** anchored to the central pulley may be equivalent to about 5 degrees of the arc of the central pulley **251**. FIG. **2**C illustrates a portion **265** of the second band **262** anchored to first level. This portion **265** is representative of the portions of the first band **261**, third band **263**, and fourth band **264** anchored to the central pulley **251**.

[0071] The first and second elbow pulleys **256***a,b* are each similarly attached to a shaft **157** of a respective arm **141**, **142**. For example, the shaft **157** may be rotatably coupled to the outer race of a respective elbow pulley **256***a,b* that rotates relative to an inner race. Thus, the rotation of the first elbow pulley **256***a* causes the rotation of the first arm **141** and the rotation of the second elbow pulley **256***b* causes the rotation of the second arm **142**. The first and second elbow pulleys **256***a,b* are each a multi-level pulley. A second end of the first band **261** is anchored to a first level of the first elbow pulley **256***a*, a second end of the second band **262** is anchored to a first level of the second elbow pulley **256***b*, a second end of the third band **263** is anchored to a second level of the first elbow pulley **256***a*, and a second end of the fourth band **264** is anchored to a second level of the second elbow pulley **256***b*. FIG. **2**C illustrates a portion **266** of the second end of the second band **262** anchored to first level of the second elbow pulley **256***b*. This portion **266** is representative of the portion of the fourth band **264** anchored to the second elbow pulley **256***b* and representative of the portion of the first band **261** and third band **263** anchored to the second elbow pulley **256***a*. In some embodiments, the portion of the second of the bands **261-264** anchored to an elbow pulley **256***a,b* may be equivalent to about 5 degrees of the arc of the elbow pulley **256***a,b*.

[0072] As shown in FIGS. **2**B and **2**C, the first band **261** and second band **262** are disposed above the third band **263** and fourth bands **264**. In other words, the pulley system **250** has stacked bands.

[0073] As the base **131** rotates, the elbow pulleys **256***a,b* rotate (e.g., orbit) around the stationary central pulley **251**. The first band **261** and third band **263** cause the first elbow pulley **256***a* to rotate as the base **131** rotates relative to the central pulley **251**, thereby rotating the first arm **141** about the first elbow axis **149***a*. Similarly, the second band **262** and fourth band **264** cause the second elbow pulley **256***b* to rotate as the base **131** moves relative to the central pulley **251**, thereby rotating the second arm **142** about the second elbow axis **149***b*.

[0074] The rotation of the swapper **230** about the central axis **132** is limited since a portion of each end of the bands **261-264** is anchored to the pulleys. For example, the base **131** may only be able to rotate about the central axis **132** from the retracted position shown in FIG. **2**B (e.g., perpendicular to the trajectory **146**) by a range, the range being less than 90 degrees of rotation. The base **131** may rotate over the range in either a clockwise or counter-clockwise direction. For example, the range of rotation of the base **131** may be between 0 degrees and 85 degrees, such as between 0 degrees and 82 degrees, such as 0 degrees and 77 degrees.

[0075] FIG. **2**A shows the swappers **230** in an extended position. As shown, the base **131** of each swapper **230** is rotated counter clockwise from the retracted position shown in FIG. **2**B. As shown, the central axis **132** and the elbow axes **149***a*, **149***b* are not aligned, such as what is shown in the second extended position of left-hand side swapper **130** of FIG. **1**A, when the swapper **230** is in the extended position due to the limitations on rotation resulting from part of the bands **261-264** being wrapped around a pulley of the pulley system **250**. The swappers **230**, however, both are operable to move the substrate **105** along the substantially linear trajectory **146**. The arms **141**, **142** may be moved to an overreach position based on the remaining ability of the pulley system **250** to rotate the arms **141**, **142**.

[0076] As shown in FIG. **2**A, the base **131** of the swapper **230** is partially disposed in the tunnel **113** and opening **173** when the swapper **230** is in the extended position. The swapper **230** is sized to fit within the tunnel **113** and opening **173** without contact. For example, and as shown in FIG. **2**B, the swapper **230** similarly has a height H**1** from the underside of the base **131** to the top of the first arm **141**. This height H**1** is less than the height of the opening of the tunnel **113** of the processing chamber **110** and the height of the opening of the opening **173** in the load lock **170**. For example, the opening **173** and tunnel **113** may have a height that is at least 50 mm. The base **131** may have a height of about 20 mm. The distance from the upper surface of the base **131** to the upper surface of the second arm **142** may also be about 20 mm. Thus, the first height may be 40 mm, thereby allowing the swapper **230** to enter and exit the opening **173** and tunnel **113** with a clearance therebetween.

[0077] FIG. **2**A shows a substrate **105** placed on the support **144** of each arm **141**, **142**. A portion of each arm **141**, **142** is shown in dashed to illustrate that the substrate **105** is supported on the corresponding arm **141**, **142**. The center point **147** of each arm **141**, **142** will follow the trajectory **146** as the motor assembly **160** operates the swapper **230** to move the arms **141**, **142**. As shown in FIG. **2**A, the trajectory **146** (shown as a line) is a substantially linear path that extends from the center point of the substrate support **112**, over the central axis **132** of the swapper **230**, to a center point of the load lock **170**. In other words, the center point **147** moves linearly as the first arm **141** and second arm **142** swap positions. The substrate **105** disposed on the support **144** of each arm **141**, **142** similarly moves in a linear fashion. Thus, the swapper **130** is used to move the substrates in a linear trajectory between the load lock **170** and processing chamber **110**, and vice versa. The arms **141**, **142** move the substrate **105** disposed thereon along parallel linear trajectories that are separated by a distance since each arm **141**, **142** is located at a different height. And, as shown in FIG. **2**A, each pair of processing chambers **110** and load locks **170** are positioned opposing each other across the swapper assembly **120** such that the linear trajectory of the substrates **105** moved by one swapper **230** is parallel to the linear trajectory of the substrates **105** moved by the other swapper **230**.

[0078] The ratio of the central pulley **251** to each elbow pulley **256***a,b* is configured to achieve a desired shape and resolution of the path (e.g., linear movement) in which the substrate **105** is transferred between the load lock **170** and processing chamber **110**. In some embodiments, the central pulley **251** has a diameter that is twice the diameter of the elbow pulleys **256***a,b* (e.g., 2:1 ratio) to achieve the linear trajectory **146**.

[0079] The base **131** of the swapper **230** similarly has a first distance D**1** extending from the central axis **132** to each elbow axis **149***a,b*. Each arm **141**, **142** similarly has a second distance D**2** between the center point **147** and the respective elbow axis **149***a,b*. The first distance D**1** and second distance D**2** are the same distance. In some embodiments, the first distance D**1** and second distance D**2** of the swapper **230** exceed the distances D**1**, D**2** of the swapper **130** shown in FIG. **1**A. The housing **122** of the swapper assembly **220** may be wider, as compared to the swapper assembly **120**, such that the swapper chamber **123** is large enough to accommodate the movement and placement of swappers **230** to prevent the two swappers **230** from contacting one another or from contacting the housing **122**.

[0080] FIG. **3**A illustrates a schematic plan view of a cluster tool **300**. The cluster tool **300** has similar components of cluster tool **100** as indicated by the reference signs without reciting the description of these components for brevity. As shown, the cluster tool **300** has a swapper assembly **320** substituted for the swapper assembly **120**. The swapper assembly **320** has similar components as the swapper assembly **120** as indicated by the reference signs without reciting the description of these components of the swapper assembly **120** for brevity.

[0081] As shown, two swappers **330** are shown disposed in the swapper chamber **123**. The swappers **330** are similar to the swappers **130**, **230** discussed above. Each swapper **330** is shown with the first arm **141** and second arm **142** a retracted (e.g., crossed) position. Each swapper **330** is configured to swap a substrate **105** disposed on an arm **141**, **142** between a load lock **170** and a processing chamber **110**. The substrates **105** are not shown on the arms **141**, **142** for clarity.

[0082] The swapper **330** of cluster tool **300** similarly has a first distance D**1** (shown in FIG. **3**B) extending between the central axis **132** and the respective elbow axis **149***a,b*. The arms **141**, **142** of swapper **330** similar have a second distance D**2** (shown in FIG. **3**B) extending between the center point **147** and the respective elbow axis **149***a,b*. The first distance D**1** and second distance D**2**, however, are not equal. The first distance D**1** is less than the second distance D**1**. In some embodiments, the second distance D**2** may exceed the first distance D**1** by more than 100 mm. The second distance D**2** may be selected based on the depth of the process station **110** such that the arms **141**, **142** can reach into the process station **110** to place the substrate **105** above the substrate support **112**.

[0083] The first distance D**1** is selected such that the ends of the base **131** are in the swapper chamber **123** but do not extend into either the opening **173** or tunnel **113** when the arms **141**, **142** are in the extended position as shown in FIG. **3**B. In other words, the ends of the elbow axes **149***a,b* are disposed in the swapper chamber **123** when the arms **141**, **142** are in the extended positions. The first arm **141** is disposed above the second arm **142**. The opening **173** and tunnel **113** of cluster tool **300** are sized to accommodate the height between the underside of the second arm **142** and the topside of the first arm **141** since the arms **141**, **142** are positioned at different heights, which is analogous to the second height H**2** shown in FIG. **1**. Thus, the height dimension of the opening **173** and tunnel **113** of cluster tool **300** may be smaller than in both cluster tools **100** and **200** since the arms **141**, **142** of the swapper **330**, and not the base **131**, extend into the opening **173** and tunnel **113**. In some embodiments, the height dimension of the opening **173** and tunnel **113** may be at least 35 mm to accommodate the arms **141**, **142** of the swapper **230**.

[0084] The second slit valve **172** is sized to cover the opening **173** and the slit valve **114** is sized to cover the tunnel **113**. A smaller dimension of the opening **173** and tunnel **113** may be covered with a smaller slit valve, and the slit valve may thus have a smaller actuator to move the slit valve between an open and closed position. Reducing and/or minimizing the height dimension of the opening **173** and tunnel **113** therefore reduce costs due to the reduction in size of the slit valve **114** and second slit valve **172**. Additionally, decreasing the size of the slit valves reduces the amount of particles caused by opening and closing the valve. Additionally, reducing the height of the tunnel **113** reduces the overall volume of the tunnel **113**, which reduces thermal non-uniformities within the processing chamber **110** while the substrate **105** is processed.

[0085] The shaft **357** of the first arm **141** of the swapper **330** is configured to allow the substrate **105** on to pass through the first elbow axis **149***a*. The shaft **357** of the first arm **141** may be a C-shaped member, such as shaft **457** in FIG. **4**B, to allow the substrate **105** on the second arm **142** to pass underneath the first arm **141** and to pass through the first elbow axis **149***a* without contacting the first arm **141**.

[0086] FIGS. **3**B-**3**F illustrate a partial plan view of the cluster tool **300** to show a sequence of operating the swapper **330** to swap the arms **141**, **142**. FIGS. **3**B-**3**D illustrate moving the first arm **141** and second arm **142** from an extended position to a retracted position. FIGS. **3**E and **3**F illustrate moving the first and second arm **142** from the retracted position to an extended position. Substrates **105**, while substrates **105** not shown on the arms **141**, **142** in FIGS. **3**B-**3**F, may be disposed on the first and second arms **141**, **142**.

[0087] The swapper **330** makes a first coordinated movement and a second coordinated movement to retract the arms **141**, **142**. The swapper **330** similarly makes a first and second coordinated movement to extend the arms **141**, **142**. FIGS. **3**B through **3**F show a trajectory taken by the center point **147** of the first arm **141** as the first arm **141** is moved from the processing chamber **110** to the load lock **170**. This trajectory is representative of the trajectory traveled by the second arm **142** while the first arm **141** is moved. As shown, the trajectory has a first trajectory segment **351** (FIG. **3**B), a second trajectory segment **352** (FIG. **3**C), a third trajectory segment **353** (FIG. **3**D), and a fourth trajectory segment **354** (FIG. **3**E).

[0088] The motor assembly **160** operates a first motor to rotate the first shaft **162** to rotate the base **131** about the central axis **132**. The swapper **330** has a pulley system, such as pulley system **150** or pulley system **250**, configured to move the arms **141**, **142** along a trajectory to extend and retract the arms **141**, **142**. The central pulley, such as central pulley **151**, **251**, is not fixed on a stationary second shaft **163**. Instead, the second shaft **163** is rotated by a second motor (see second motor **405** in FIG. **4**B), allowing the central pulley to be rotated about the central axis **132**. The second motor is selectively operated to rotate the central pulley to rotate the elbow pulley connected to each arm **141**, **142**, such as elbow pulleys **156***a*, **156***b* or elbow pulleys **256***a*, **256***b*, thereby rotating the arms **141**, **142** relative to the base **131**. The movement of the base **131** and arms **141**, **142** are coordinated to move each arm **141**, **142** along the trajectory. In some embodiments, the elbow pulleys of the swapper **330** may have a non-circular profile, such as a cam profile, unlike elbow pulleys **156***a*,*b* and elbow pulleys **256***a*,*b*, to move the arm **141**, **142** along the desired trajectory due to the dimensions of first distance D**1** and the second distance D**2**.

[0089] FIG. **3**B illustrates the arms **141**, **142** of the swapper **330** in an extended position. The first arm **141** is in the processing chamber **110** and the second arm **142** is in the load lock **170**. The first trajectory segment **351** is shown as a dashed line. The first trajectory segment **351** shows the travel path of the center point **147** of the first arm **141** from the extended position shown in FIG. **3**B to the partially retracted position shown in FIG. **3**C. The swapper **330** makes a first coordinated retraction movement to move the first arm **141** from the extended position to the partially retracted position along the first trajectory segment **351**. The first motor causes the base **131** to rotate about the central axis **132** in a clockwise direction. The second motor simultaneously actuates the pulley system to rotate the first arm **141** in a counter clockwise direction to move the center point **147** along the first trajectory segment **351**. As shown in FIG. **3**B, the first trajectory segment **351** is a substantial linear path that withdraws the center point **147** from the processing chamber **110** through the tunnel **113** and into the swapper chamber **123**. The substantially linear path of the first trajectory segment **351** allows the substrate **105** to be moved with the first arm **141** without contacting an interior surface of the processing chamber **110**. The first trajectory segment **351**, as shown in FIG. **3**B, extends along an axis **301** that extends through the centers of the processing chamber **110** and load lock **170** as well as through the central axis **132** of the swapper **330**. The second arm **142** will make a similar movement as the first arm **141** to move from the extended position shown in FIG. **3**B to the partially retracted position shown in FIG. **3**C.

[0090] FIG. **3**C shows the first arm **141** in the partially retracted position after following the first trajectory segment **351** from the extended position shown in FIG. **3**B. The second arm **142** is similarly in the partially retracted position. The second trajectory segment **352** is shown as a dashed line. The second trajectory segment **352** shows the travel path of the center point **147** of the first arm **141** from the partially retracted position shown in FIG. **3**C to the retracted position shown in FIG. **3**D. As shown, the second trajectory segment **352** extends at an angle relative to the first trajectory segment **351** and is thus disposed at an angle relative to the axis **301**. The swapper **330** makes a second coordinated retraction movement to move the first arm **141** from the partially retracted position shown in FIG. **3**C to the retracted position shown in FIG. **3**D. The first motor causes the base **131** to rotate about the central axis **132** in a counter clockwise direction from the position shown in FIG. **3**C. The second motor simultaneously actuates the pulley system to rotate the first arm **141** in the counter clockwise direction to move the center point **147** along the second trajectory segment **352**. The second trajectory segment **352** is shown as a being substantially linear. The non-circular profile of the elbow pulleys facilitates this substantially linear trajectory of the second trajectory segment **352**. In some embodiments, the second trajectory segment **352** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. For example, the second trajectory segment **352** may be an arcuate trajectory if the elbow pulleys have a non-circular profile. The second arm **142** will make a similar movement as the first arm **141** to move from the partially retracted position shown in FIG. **3**C to the retracted position shown in FIG. **3**D.

[0091] FIG. **3**D shows the arms **141**, **142** of the swapper **330** in the retracted position. The swapper **230** is further operated to move the first arm **141** into the load lock **170**. The third trajectory segment **353** is shown as a dashed line. The third trajectory segment **353** shows the travel path of the center point **147** of the first arm **141** from the retracted position shown in FIG. **3**D to a partially extended position shown in FIG. **3**E. As shown, the third trajectory segment **353** extends at an angle relative to the second trajectory segment **352** and is thus disposed at an angle relative to the axis **301**. The swapper **330** makes a first coordinated extension movement to move the first arm **141** from the retracted position shown in FIG. **3**D to the partially extended position shown in FIG. **3**E. The first motor causes the base **131** to rotate about the central axis **132** in a counter clockwise direction from the position shown in FIG. **3**D. The second motor simultaneously actuates the pulley system to rotate the first arm **141** in the counter clockwise direction to move the center point **147** along the third trajectory segment **353**. The third trajectory segment **353** is shown as a being substantially linear. In some embodiments, the second trajectory segment **352** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. The second arm **142** will make a similar movement as the first arm **141** to move from the retracted position shown in FIG. **3**D to the partially extended position shown in FIG. **3**E.

[0092] FIG. **3**E shows the arms **141**, **142** of the swapper **330** in the partially extended position. The swapper **330** is further operated to move the first arm **141** into the load lock **170**. The fourth trajectory segment **354** is shown as a dashed line. As shown, the fourth trajectory segment **354** is at an angle relative to the third trajectory segment **353**, and the fourth trajectory segment **354** is collinear with the axis **301**. The swapper **330** makes a second coordinated extension movement to move the first arm **141** from the partially extended position shown in FIG. **3**E to the extended position shown in FIG. **3**F. The first motor causes the base **131** to rotate about the central axis **132** in a clockwise direction from the position shown in FIG. **3**E. The second motor simultaneously actuates the pulley system to rotate the first arm **141** in the counter clockwise direction to move the center point **147** along the fourth trajectory segment **354**. The second arm **142** will make a similar movement as the first arm **141** to move from the partially extended position shown in FIG. **3**E to the extended position shown in FIG. **3**F.

[0093] FIG. **3**F shows the swapper **330** in an extended position such that the first arm **141** is disposed within the load lock **170** and the second arm **142** is positioned within the processing chamber **110**. In other words, the first arm **141** and second arm **142** has swapped positions with the placement shown in FIG. **3**B. The first arm **141** and second arm **142** may be returned to the extended position shown in FIG. **3**B by reversing the movements of the swapper **330**. The swapper **330** can move as described to swap substrates **105** disposed on the arms **141**, **142** between the processing chamber **110** and the load lock **170**.

[0094] In some embodiments, the swapper **330** is extended to place a substrate **105** into the processing chamber **110**. After the substrate **105** is transferred to the lift pins of the substrate support **112**, the swapper **330** may be moved to the retracted position to allow the slit valve **114** to close during processing.

[0095] The swapper **330** allows for center correction of the substrate **105** in both the X and Y directions. FIG. **3**A shows the X and Y directions, the X-direction extending in the same direction of the axis **301** and the Y-direction being perpendicular to the X-direction. For example, the first and second motor may coordinate the movement of the base **131** and arms **141**, **142** to align the center of the substrate **105**, which is offset from the center point **147** in both the X and Y directions, above the center point of the processing chamber **110** and load lock **170**.

[0096] FIG. **4**A illustrates a partial plan view of an exemplary cluster tool **400**. The cluster tool **400** has similar components as the cluster tool **100** as indicated by the reference signs without reciting the description of these components for brevity. As shown, the cluster tool **400** has a swapper assembly **420** substituted for the swapper assembly **120**. The swapper assembly **420** has similar components as the swapper assembly **120** as indicated by the reference signs without reciting the description of these components of the swapper assembly **120** for brevity. FIG. **4**A illustrates one load lock **170** paired with a processing chamber **110** with a swapper **430** of the swapper assembly **420** shown in between. The cluster tool **400** may have multiple pairs of load locks **170** and processing chambers **110**, each pair having a swapper **430** disposed between.

[0097] As shown, a swapper **430** is shown disposed in the swapper chamber **123** of the swapper assembly **420**. The swapper **430** is similar to the swappers **130**, **230** discussed above. The swapper **430** is shown in an extended position with the first arm **141** disposed in the processing chamber **110** and the second arm **142** disposed in the load lock **170**. A substrate **105** is not shown on the arms **141**, **142**. Each swapper **430** is configured to swap a substrate **105** disposed on an arm **141**, **142** between a load lock **170** and a processing chamber **110**.

[0098] The swapper **430** includes a base **131**, a first arm **141**, a second arm **142**, a first link **441**, a second link **442**, and a pulley system **450** (shown in FIG. **4**B). The first arm **141** is pivotally connected to the first link **441**. The second arm **142** is pivotally connected to the second link **442**. The first and second links **441**, **442** are each pivotally connected to the base **131**. The pulley system **450** is configured to move the first link **441**, second link **442**, first arm **141**, and second arm **142**.

[0099] As shown in FIG. **4**B, the pulley system **450** includes a base pulley assembly **460** disposed in the base **131** and a link pulley system **470** disposed in each of the first link **441** and the second link **442**. The base pulley assembly **460** includes a first base pulley system **460***a* and a second base pulley system **460***b*.

[0100] The first base pulley system **460***a* is similar to the pulley system **250** shown in FIG. **2**B, in that the first base pulley system **460***a* includes multi-leveled pulleys with band segments extending between the pulleys. As shown, the first base pulley system **460***a* includes a first central pulley **451**, a first elbow pulley **256***a*, and a second elbow pulley **256***b*. The first base pulley system **460***a* further includes a first band **461**, a second band **462**, a third band **463**, and a fourth band **464**. In some embodiments, each of the bands **461-464** may include an inline tensioner **155**.

[0101] The first central pulley **451** is coupled to a third shaft **402** extending through the first shaft **162** and the second shaft **163**. The first shaft **162** and second shaft **163** are independently rotatable relative to the third shaft **402**. In some embodiments, the first central pulley **451** is a fixed (e.g., stationary) pulley mounted on a fixed (e.g., stationary) shaft **402** similar to central pulley **151**. The base **131** is rotatable about the central axis **132**, and thus rotatable relative to the first central pulley **451**, by the first motor **161** (FIGS. **1**B, **2**B) of the motor assembly **160** that rotates the first shaft **162** to rotate the base **131**. The first central pulley **451** has two levels to accommodate the bands **461-464** similar to central pulley **251** shown in FIG. **2**C.

[0102] As explained above, the elbow pulleys **256***a*,*b* are two leveled pulleys. In some embodiments, the inner race of the first elbow pulleys **256***a* may be mounted to a link shaft **476** of the first link **441**. The outer race of the first elbow pulley **256***a* may thus rotate about the link shaft **476** of the first link **441**. The outer race of the first elbow pulley **256***a* is rotatably coupled to the first link **441** and coupled to the first band **461** and second band **462**. The rotation of the first elbow pulley **256***a* caused by the first band **461** and second band **462** also causes the first link **441** to rotate relative to the base **131**. The inner race of the second elbow pulley **256***b* may be mounted to a link shaft **476** of the second link **442**. The outer race of the second elbow pulley **256***b* may thus rotate about the link shaft **476** of the second link **442**. The outer race of the second elbow pulley **256***b* is rotatably coupled to the second link **442** and coupled to the third band **463** and fourth band **464**. The rotation of the second elbow pulley **256***b* caused by the third and fourth bands **463**, **464** also causes the second link **442** to rotate relative to the base **131**.

[0103] The first band **461** and the second band **462** extend between the first central pulley **451** and the first elbow pulley **256***a*. A first end of the first band **461** is anchored to a first level of the first central pulley **451** and the second end of the first band **461** is anchored to a first level of the first elbow pulley **256***a*. A first end of the second band **462** is anchored to a second level of the first central pulley **451** and the second end of the second band **462** is anchored to a second level of the first elbow pulley **256***a*. However, the first and second bands **461**, **462** do not extend parallel to one another between the pulleys similar to what is shown in in FIG. **2**C. Instead, the first and second bands **461**, **462** pass over (e.g., cross over) one another and are arranged in a "FIG. **8**" configuration. As shown, the first end of the first band **461** extends from a first side of the first central pulley **451** while the second end of first band **461** extends to a second side of the first elbow pulley **256***a*. Similarly, the first end of the second band **462** extends from a second side of the first central pulley **451** while the second end of second band **462** extends to a first side of the first elbow pulley **256***a*. This configuration of the first band **461** and the second band **462** causes the first link **441** to rotate in the same rotational direction as the base **131**, as the base **131** is rotated relative to the first central pulley **451**.

[0104] The third band **463** and the fourth band **464** extend between the first central pulley **451** and the second elbow pulley **256***b*. A first end of the third band **463** is anchored to the first level of the first central pulley **451** and the second end of the third band **463** is anchored to a first level of the second elbow pulley **256***b*. A first end of the fourth band **463** is anchored to the second level of the first central pulley **451** and the second end of the fourth band **464** is anchored to a second level of the second elbow pulley **256***b*. The third and fourth bands **463**, **464** similarly pass over one another and are arranged in a "FIG. **8**" configuration. As shown, the first end of the third band **463** extends from the second side of the first central pulley **451** while the second end of the third band **463** extends to a first side of the second elbow pulley **256***b*. Similarly, the first end of the fourth band **464** extends from the first side of the first central pulley **451** while the second end of the fourth band **464** extends to a first side of the second elbow pulley **256***b*. This configuration of the third band **463** and the fourth band **464** causes the second link **442** to rotate in the same rotational direction as the base **131** as the base **131** is rotated relative to the first central pulley **451**.

[0105] In some embodiments, the first central pulley **451** and elbow pulleys **256***a,b* have a 1:1 ratio to facilitate moving the center point **147** of each arm **141**, **142** along a trajectory. In other words, every unit of rotation of the base in a rotational direction similarly causes the same unit of rotation of first link **441** and the second link **442**.

[0106] The second base pulley system **460***b* includes a second central pulley **491**, a first pulley **492***a*, and a second pulley **492***b*. The second central pulley **491** is fixed to the second shaft **163** extending through the first shaft **162**. The second shaft **163** is rotatable by a second motor **405** of the motor assembly **160** to rotate the second central pulley **491** about the central axis **132**. The second central pulley **491** is a multi-level pulley. In some embodiments, a first belt **493** may be engaged with a first level of the second central pulley **491** and a second belt **494** may be engaged with a second level of the second central pulley **491**. The first belt **493** is looped around the first pulley **492***a* and the second central pulley **491**. The second belt **494** is looped around the second pulley **492***b* and the second central pulley **491**. Thus, the rotation of the second central pulley **491** causes the first and second pulleys **492***a,b* to rotate. In some embodiments, two band segments may extend between the second central pulley **491** and each pulley **492***a,b* in a similar manner as pulley system **250**. In some embodiments, the second central pulley **491** and the pulleys **492***a,b* have a 1:1 ratio to facilitate moving the center point **147** of each arm **141**, **142** along the trajectory. An inner race of the pulleys **492***a,b* may be mounted on a mounting shaft **136** of the base **131**.

[0107] Each link **441**, **442** has a link pulley system **470** disposed in a link chamber **444** formed within the respective link **441**, **442**. Each link pulley system **470** includes a first link pulley **471** and a second link pulley **472**. A belt **473** is looped around the first link pulley **471** and second link pulley **472**. The belt **473** causes the second link pulley **472** to rotate in response to the rotation of the first link pulley **471**. In some embodiments, the belt **473** may instead be two segments extending between the first link pulley **471** and the second link pulley **472**. The first link pulley **471** is rotatably coupled to one of the pulleys **492***a*,*b* of the second base pulley system **460***b*. In other words, the rotation of the pulleys **492***a*,*b* causes the first link pulley **471** connected thereto to rotate. The first link pulley **471** may be coupled to the link shaft **476** that extends through an opening in the bottom of the respective link **441**, **442**. Thus, one end of the link shaft **446** is rotatably connected to the one of the pulleys **492***a*,*b* while the other end is rotatably connected to one of the first link pulleys **471**. In some embodiments, the link shaft **476** is rotatably connected with an outer race of the respective pulleys **492***a*,*b*. The rotation of the outer race of the first pulley **492***a* causes the first link pulley **471** in the first link **441** to rotate. The rotation of the outer race of the second pulley **492***b* causes the first link pulley **471** in the second link **442** to rotate.

[0108] The second link pulley **472** may be mounted on and rotate about a mounting shaft **477** fixed to a wall of the respective link **441**, **442**. The second link pulley **472** may have an inner race mounted to the shaft **477** and an outer race rotatable about the inner race that is engaged with and rotated by the belt **473**. The second link pulley **472** of the first link **441** is rotatably coupled to the c-shaped shaft **445** of the first arm **141**, such rotation of the second link pulley **472** by the belt **473** causes the first arm **141** to rotate. The second link pulley **472** of the second link **442** is rotatably coupled to the shaft **157** of the second arm **142**, such that rotation of the second link pulley **472** by the belt **473** causes the second arm **142** to rotate.

[0109] The second motor **405** is used to actuate the second base belt assembly **460***a* and the two link pulley systems **470** to rotate the first arm **141** and the second arm **142** relative to the base **131** and relative to the respective link **441**, **442**. The first motor **161** is used to rotate the base **131** which causes the links **441**, **442** to rotate in the same direction as the base **131** due to the first base pulley system **460***a*. The first motor **161** and the second motor **405** of the motor assembly **160** are coordinated to move the center point **147** of each of the arms **141**, **142** along a desired trajectory. In some embodiments, the first link pulley **471** and the second link pulley **472** have a 1:1 ratio to facilitate moving the center point **147** of each arm **141**, **142** along a trajectory.

[0110] The central axis **132** of the swapper **430** extends thorough the first central pulley **451** fixed on the third shaft **402**. The first elbow pulley **256***a*, the first pulley **492***a*, and the first link pulley **471** disposed in the first link **441** rotate about an elbow axis **410**. The second elbow pulley **256***b*, the second pulley **492***b*, and the first link pulley **471** disposed in the second link **442** similarly rotate about an elbow axis **410**. Each second link pulley **472**, and the respective arm **141**, **142** attached thereto, rotates about an arm axis **411**. In other words, each link **441**, **442** rotates relative to the base **131** about an elbow axis **410**, the first arm **141** rotates relative to the first link **441** about an arm axis **411**, and the second arm **142** rotates relative to the second link **442** about an arm axis **411**.

[0111] The swapper **430** of cluster tool **400** similarly has a first distance X**1** (shown in FIG. **4**A) extending between the central axis **132** and the respective elbow axis **410**. The arms **141**, **142** of swapper **430** have a second distance X**2** (shown in FIG. **4**A) extending between the center point **147** and the respective arm axis **411**. The links **441**, **442** each have a third distance X**3** (shown in FIG. **4**A) extending from the respective elbow axis **410** to the respective arm axis **411**. The first distance X**1** and second distance X**2** are not equal distances. The first distance X**1** is less than the second distance X**2**. In some embodiments, the second distance X**2** may exceed the first distance X**1** by more than 200 mm. In some embodiments, and as shown in FIG. **4**A, the first distance X**1** and third distance X**3** are equivalent distances. The first distance X**1**, second distance X**2**, and third distance X**3** may be selected based on the depth of the process chamber **110** such that the arms **141**, **142** can reach into the process chamber **110** to place the substrate **105** above the substrate support **112**.

[0112] The first distance X**1** and third distance X**3** are selected such that the ends of the base **131** and the ends of the links **441**, **442** are in the swapper chamber **123** but do not extend into either the opening **173** or tunnel **113** when the arms **141**, **142** are in the extended position as shown in FIG. **4**A. In other words, the arm axes **411** are disposed in the swapper chamber **123** when the arms **141**, **142** are in the extended positions. The first arm **141** is disposed above the second arm **142**. The opening **173** and tunnel **113** of cluster tool **400** are sized to accommodate the height between the underside of the second arm **142** and the topside of the first arm **141** since the arms **141**, **142** are positioned at different heights (similar to the height H**2** shown in FIG. **1**B). Thus, the height dimension of the opening **173** and tunnel **113** of cluster tool **400** may be smaller than in cluster tools **100** and **200** since the arms **141**, **142** of the swapper **430**, and not the base **131** or links **441**, **442**, extend into the opening **173** and tunnel **113**. In some embodiments, the height dimension of the opening **173** and tunnel **113** may be between 30 mm to 50 mm, such as 35 mm, such as 40 mm, such as 45 mm, to accommodate the arms **141**, **142** of the swapper **430**. Reducing and/or minimizing the size of the opening **173** and tunnel **113** provides similar benefits as described above with respect to cluster tool **300**.

[0113] The swapper **430** has a reduced overall length (from end to end) when in the retracted position (e.g., FIG. **4**E) as compared to the swapper **330**. In other words, the swappers **430** are more compact when in the retracted position than the swappers **330**. Therefore, two swappers **430** may be housed in a smaller swapper chamber **123** as compared to two swappers **330**.

[0114] The shaft **445** of the first arm **141** of the swapper **430** is configured to allow the substrate **105** on the second arm **142** to pass through the arm axis **411**. The shaft **445** of the first arm **141** may be a C-shaped member, such as to allow the substrate **105** on the second arm **142** to pass underneath the first arm **141** without contacting the first arm **141**.

[0115] The swapper **430** makes a first coordinated retraction movement, a second coordinated retraction movement, and a third coordinated retraction movement to retract the arms **141**, **142** from an extended position. The swapper **430** similarly makes a first coordinated extension movement, a second coordinated extension movement, and a third coordinated extension movement to extend the arms **141**, **142** from the retracted position. FIGS. **4**A and **4**C-**4**H show a trajectory taken by the first arm **141** as the first arm **141** is moved from the processing chamber **110** to the load lock **170**. This trajectory is representative of the trajectory traveled by the second arm **142** while the first arm **141** is moved. As shown, the trajectory has a first trajectory segment **481** (FIG. **4**A), a second trajectory segment **482** (FIG. **4**C), a third trajectory segment **483** (FIG. **4**D), a fourth trajectory segment **484** (FIG. **4**E), a fifth trajectory segment **485** (FIG. **4**F) and a sixth trajectory segment **486** (FIG. **4**G). FIG. **4**A shows the arms **141**, **142** in the extended position, with the first arm **141** disposed in the processing chamber **110** and the second arm **142** disposed in the load lock **170**. FIG. **4**H shows the arms **141**, **142** in the extended position after moving along the trajectory, in that the first arm **141** is now in the load lock **170** and the second arm **142** is now in the processing chamber **110**.

[0116] The pulley system **450** is configured to move the arms **141**, **142** along a trajectory to extend and retract the arms **141**, **142**. The motor assembly **160** operates a first motor **161** to rotate the first shaft **162** to rotate the base **131** about the central axis **132** and to rotate the base **131** relative to the first central pulley **451**. The bands **461-464** cause the elbow pulleys **256***a,b* to rotate as the base **131** rotates relative to the first central pulley **451**, thereby causing the links **441**, **442** to rotate about the elbow axis **410**. The second central pulley **491** is rotated about the central axis **132** by the second motor **405** of the motor assembly **160**. The first motor **161** and the second motor **405** are coordinated to move the first link **441**, second link **442**, first arm **141**, and second arm **142** such that the center point **147** of each arm **141**, **142** follows along a desired trajectory.

[0117] FIG. **4**A illustrates the arms **141**, **142** of the swapper **430** in an extended position. The first arm **141** is in the processing chamber **110** and the second arm **142** is in the load lock **170**. The first trajectory segment **481** is shown as a dashed line. The first trajectory segment **481** shows the travel path of the center point **147** of the first arm **141** from the extended position shown in FIG. **4**A to a first partially retracted position shown in FIG. **4**C. The swapper **430** makes a first coordinated retraction movement to move the first arm **141** from the extended position to the first partially retracted position along the first trajectory segment **481**. The first motor **161** causes the base **131** to rotate about the central axis **132** in a clockwise direction, causing the first link **441** and the second link **442** to rotate relative to the base **131** in the clockwise direction. The second motor **405** simultaneously actuates the second pulley system **460***b* and link pulley system **470** in the first link **441** to rotate the first arm **141** in a counter clockwise direction to move the center point **147** along the first trajectory segment **481**. As shown in FIG. **4**A, the first trajectory segment **481** is a substantial linear path that moves center point **147** toward the tunnel **113**. The substantially linear path of the first trajectory segment **481** allows the substrate **105** to be moved with the first arm **141** without contacting an interior surface of the processing chamber **110**. The first trajectory segment **481**, as shown in FIG. **4**A, extends along an axis **401** that extends through the centers of the processing chamber **110** and load lock **170** as well as through the central axis **132** of the swapper **430**. The second arm **142** will make a similar movement as the first arm **141** to move from the extended position shown in FIG. **4**A to the first partially retracted position shown in FIG. **4**C.

[0118] FIG. **4**C shows the first arm **141** in the first partially retracted position after following the first trajectory segment **481** from the extended position shown in FIG. **4**A. The second arm **142** is similarly in the first partially retracted position. The second trajectory segment **482** is shown as a dashed line. The second trajectory segment **482** shows the travel path of the center point **147** of the first arm **141** from the first partially retracted position shown in FIG. **4**C to the second partially retracted position shown in FIG. **4**D. As shown, the second trajectory segment **482** extends at an angle relative to the first trajectory segment **481** and is thus disposed at an angle relative to the axis **401**. In some embodiments, the first trajectory segment **482** may be collinear with the first trajectory segment **481**. The swapper **430** makes a second coordinated retraction movement to move the first arm **141** from the first partially retracted position shown in FIG. **4**C to the second partially retracted position shown in FIG. **4**D. The first motor **161** causes the base **131** to rotate clockwise about the central axis **132** from the position shown in FIG. **4**C. The rotation of the base **131** relative to the first central pulley **451** causes the first base pulley system **460***a* to rotate first link **441** and the second link **442** in a clockwise direction relative to the base **131**. The second motor **405** simultaneously actuates the second base pulley system **460***b* and the link pulley system **470** of the first link **441** to rotate the first arm **141** in a counter-clockwise direction to move the center point **147** along the second trajectory segment **482**. The second trajectory segment **482** is shown as a being substantially linear. In some embodiments, the elbow pulleys **256***a*,*b* have a non-circular profile to facilitate this substantially linear trajectory of the second trajectory segment **482**. In some embodiments, the second trajectory segment **482** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. The second arm **142** will make a similar movement as the first arm **141** to move from the first partially retracted position shown in FIG. **4**C to the second partially retracted position shown in FIG. **4**D.

[0119] FIG. **4**D shows the first arm **141** in the second partially retracted position after following the second trajectory segment **482** from the first partially retracted position shown in FIG. **4**C. The center point **147** of the first arm **141** is shown as withdrawn from the tunnel **113** and is now located within the swapper assembly **420**. The second arm **142** is similarly in the second partially retracted position. The third trajectory segment **483** is shown as a dashed line. The third trajectory segment **483** shows the travel path of the center point **147** of the first arm **141** from the second partially retracted position shown in FIG. **4**D to the retracted position shown in FIG. **4**E. As shown, the third trajectory segment **483** extends at an angle relative to the second trajectory segment **482** and is thus disposed at an angle relative to the axis **401**. The swapper **430** makes a third coordinated retraction movement to move the first arm **141** from the second partially retracted position shown in FIG. **4**D to the retracted position shown in FIG. **4**E. The first motor **161** causes the base **131** to rotate about the central axis **132** in the counter clockwise direction from the position shown in FIG. **4**D. The rotation of the base **131** relative to the first central pulley **451** causes the first base pulley system **460***a* to rotate first link **441** and the second link **442** in the counter-clockwise direction relative to the base **131**. The second motor **405** simultaneously actuates the second base pulley system **460***b* and the link pulley system **470** of the first link **441** to rotate the first arm **141** in a counter-clockwise direction to move the center point **147** along the third trajectory segment **483**. The third trajectory segment **483** is shown as a being substantially linear. In some embodiments, the non-circular profile of the elbow pulleys **256***a,b* facilitates this substantially linear trajectory of the third trajectory segment **483**. In some embodiments, the third trajectory segment **483** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. The second arm **142** will make a similar movement as the first arm **141** to move from the second partially retracted position shown in FIG. **4**D to the retracted position shown in FIG. **4**E.

[0120] FIG. **4**E shows the arms **141**, **142** of the swapper **430** in the retracted position. The first arm **141** is positioned over the second arm **142**. The first arm **141** is also partially disposed over the second link **442** and the second arm **142** is partially disposed over the first link **441**. The first and second links **441**, **442** and the first and second arms **141**, **142** are positioned such that the elbow axis **410** and the arm axis **411** are positioned perpendicular to the axis **401**.

[0121] The swapper **430** is further operated from the retracted position to move the first arm **141** into the load lock **170**. The fourth trajectory segment **484** is shown as a dashed line in FIG. **4**E. The fourth trajectory segment **484** shows the travel path of the center point **147** of the first arm **141** from the retracted position shown in FIG. **4**E to a first partially extended position shown in FIG. **4**F. As shown, the fourth trajectory segment **484** extends at an angle relative to the third trajectory segment **483** and is thus disposed at an angle relative to the axis **401**. The swapper **430** makes a first coordinated extension movement to move the first arm **141** from the retracted position shown in FIG. **4**E to the first partially extended position shown in FIG. **4**F along the fourth trajectory segment **484**. The first motor **161** causes the base **131** to rotate about the central axis **132** in the counter-clockwise direction from the position shown in FIG. **4**E. The rotation of the base **131** relative to the first central pulley **451** causes the first base pulley system **460***a* to rotate first link **441** and the second link **442** in the counter-clockwise direction relative to the base **131**. The second motor **405** simultaneously actuates the second base pulley system **460***b* and the link pulley system **470** of the first link **441** to rotate the first arm **141** in the counter clockwise direction to move the center point **147** along the fourth trajectory segment **484**. The fourth trajectory segment **484** is shown as a being substantially linear. In some embodiments, the fourth trajectory segment **484** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. The second arm **142** will make a similar movement as the first arm **141** to move from the retracted position shown in FIG. **4**E to the first partially extended position shown in FIG. **4**F.

[0122] FIG. **4**F shows the arms **141**, **142** of the swapper **430** in the first partially extended position. The swapper **430** is further operated to move the first arm **141** into the load lock **170**. The fifth trajectory segment **485** is shown as a dashed line. As shown, the fifth trajectory **485** is at an angle relative to the fourth trajectory segment **484**, and the fifth trajectory segment **485** is angled with respect to the axis **401**. The swapper **430** makes a second coordinated extension movement to move the first arm **141** from the first partially extended position shown in FIG. **4**F to a second partially extended position shown in FIG. **4**G. The first motor **161** causes the base **131** to rotate about the central axis **132** in the clockwise direction from the position shown in FIG. **4**F. The rotation of the base **131** relative to the first central pulley **451** causes the first base pulley system **460***a* to rotate first link **441** and the second link **442** in the clockwise direction relative to the base **131**. The second motor **405** simultaneously actuates the second base pulley system **460***b* and the link pulley system **470** of the first link **441** to rotate the first arm **141** in the counter-clockwise direction to move the center point **147** along the fifth trajectory segment **485**. FIG. **4**F shows the fifth trajectory segment **485** as being substantially linear. In some embodiments, the fifth trajectory segment **485** may be collinear with the sixth trajectory segment **486**. In some embodiments, the fifth trajectory segment **485** may not be substantially linear, but instead may be another non-linear trajectory, such as being an arcuate trajectory. The second arm **142** will make a similar movement as the first arm **141** to move from the first partially extended position shown in FIG. **4**F to the second partially extended position shown in FIG. **4**G.

[0123] FIG. **4**G shows the arms **141**, **142** of the swapper **430** in the second partially extended position. The swapper **430** is further operated to move the first arm **141** into the load lock **170**. The sixth trajectory segment **486** is shown as a dashed line. As shown, the sixth trajectory segment **486** is at an angle relative to the fifth trajectory segment **485**, and the sixth trajectory segment **486** is collinear with the axis **401**. The swapper **430** makes a third coordinated extension movement to move the first arm **141** from the second partially extended position shown in FIG. **4**G to the extended position shown in FIG. **4**H. The first motor **161** causes the base **131** to rotate about the central axis **132** in the clockwise direction from the position shown in FIG. **4**F. The rotation of the base **131** relative to the first central pulley **451** causes the first base pulley system **460***a* to rotate first link **441** and the second link **442** in a clockwise direction relative to the base **131**. The second motor **405** simultaneously actuates the second base pulley system **460***b* and the link pulley system **470** of the first link **441** to rotate the first arm **141** in the counter-clockwise direction to move the center point **147** along the sixth trajectory segment **486**. The second arm **142** will make a similar movement as the first arm **141** to move from the second partially extended position shown in FIG. **4**G to the extended position shown in FIG. **4**H.

[0124] FIG. **4**H shows the swapper **430** in an extended position such that the first arm **141** is disposed within the load lock **170** and the second arm **142** is positioned within the processing chamber **110**. In other words, the first arm **141** and second arm **142** have swapped positions with the placement shown in FIG. **4**A. The first arm **141** and second arm **142** may be returned to the extended position shown in FIG. **4**A by reversing the movements of the swapper **430**. The swapper **430** can move moved as described to swap substrates **105** disposed on the arms **141**, **142** between the processing chamber **110** and the load lock **170**.

[0125] In some embodiments, the swapper **430** is extended to place a substrate **105** into the processing chamber **110**. After the substrate **105** is transferred to the lift pins of the substrate support **112**, the swapper **430** may be moved to the retracted position to allow the slit valve **114** to close during processing.

[0126] The swapper **430** allows for center correction of the substrate **105** in both the X and Y directions in a similar manner as described with swapper **430** as the first and second motor **405** can be used to coordinate the position of the first and second arms **141**, **142** to center an offset substrate disposed thereon over the center of either the load lock **170** or the center of the substrate support **112**.

[0127] FIG. **5** illustrates a partial exploded view of a belt system **500** to show an in-line tensioner **510**. The in-line tensioner **510** is connected to a first belt portion **501** and a second belt portion **502**. The first and second belt portions **501**, **502** may be part of a belt that loops around two pulleys, similar to belt **153** shown in FIG. **1**B, or are part of a band that is anchored to two pulleys, such as band **251** shown in FIG. **2**B. The in-line tensioner **510** allows the belt or band that it is connected to experience a desired tension. The tensioner **155** described herein may be the in-line tensioner **510**.

[0128] The in-line tensioner **510** includes a block **520** and a biasing element **530**. The block **520** includes a channel, such as a C-shaped channel shown in FIG. **5**, running between both ends of the block **520**. The block **520** also includes first block fastener openings **524** that are disposed within the channel **522**. The biasing element **530** is disposed with in the channel **522**.

[0129] The biasing element **530** includes a first portion **531**, a second portion **532**, and a third portion **533**. The first portion **531** and second portion **532** may be rectangular elements as shown in FIG. **5**. The third portion **533** is disposed between the first portion **531** and the second portion **532**. Third portion **533** is a biasing member, such as a spring cut or machined into the biasing element

530. FIG. **5** shows the portion **533** including a plurality of spring slots **535** with the spring including a plurality of "U" shaped turns extending from the first portion **531** to the second portion **532**. The spring slots **535** extend from a first side **536** of the biasing element **530** to a second side **537** of the biasing element **530**. An upper surface **538** of the biasing element **530** is partially defined by the third portion **533**, in that the upper surface **538** defines one or more of the spring slots **535**. Similarly, a lower surface **539** of the biasing element **530** is partially defined by one or more of the spring slots **535**. Thus, the third portion **533** may be a linear spring as shown in FIG. **5** rather than being a coiled spring. The third portion **533** is biased toward a neutral state, shown in FIG. **5**, in that the third portion **533** will tend to pull the first belt portion **501** and the second belt portion **502** toward each other.

[0130] The first portion **531** and second portion **532** each include at least one belt fastener opening **534**. The first belt portion **501** may be secured to the first portion **531** of the biasing element **530** by a belt fastener **540** inserted into an opening **503** in the first belt portion **501** and into the belt fastener opening **534** in the first portion **531**. Similarly, the second belt portion **502** may be secured to the second portion **532** of the biasing element **530** by a belt fastener **540** inserted into an opening **503** in the second belt portion **502** and into the belt fastener opening **534** in the second portion **532**. The belt fastener **540** may be a screw or a bolt.

[0131] The biasing element **530** further includes a slot **561** and at least one second block fastener opening **562**. FIG. **5** shows the slot **561** formed in the first portion **531** and the second block fastener opening **562** formed in the second portion **532**.

[0132] A block fastener **550** is inserted through the second block fastener opening **562** and into one of the first block fastener openings **524** to secure the first portion **531** of the biasing element **530** to the block **520**. In other words, the second portion **532** of the biasing element **530** is held in a fixed position relative to the block **520** by the block fastener **550**.

[0133] The slot **561** extends along the longitudinal axis of the biasing element **530** and further extends from the first side **536** to the second side **537**. A block fastener **550** may be inserted into the slot **561** and into a first block fastener opening **524**. The block fastener **550** may slide in the slot **561**. Thus, the slot **561** allows the first portion **531** and the third portion to move relative to the block **520** and relative to the fixed second portion **532** when the block fastener **550** is inserted into the slot **561**. In other words, the slot **561** allows the third portion **533** to apply tension to the belt by biasing the first belt portion **501** towards the second belt portion **502** that is fixed to the block **520**.

[0134] 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.

Claims

1. A swapper for a cluster tool, comprising: a base including an interior chamber, wherein the base is rotatable about a central axis; a pulley system at least partially disposed in the interior chamber, the pulley system including: a multi-level central pulley, wherein the base is rotatable relative to the multi-level central pulley; a first elbow pulley rotatable about a first elbow axis; a second elbow pulley rotatable about a second elbow axis; a first belt looping around a first level of the multi-level central pulley and the first elbow pulley; and a second belt looping around a second level of the multi-level central pulley and the second elbow pulley; and a first arm rotationally coupled to the first elbow pulley such that rotation of the first elbow pulley rotates the first arm about the first elbow axis; and a second arm rotationally coupled to the second elbow pulley such that rotation of the second elbow pulley rotates the second arm about the second elbow axis.

2. The swapper of claim 1, wherein: the base has a first distance between the central axis and the first elbow axis; and the first arm has a second distance between a central point of a support of the first arm to the first elbow axis, wherein the first distance and the second distance are equivalent distances.

3. The swapper of claim 1, further comprising: a motor assembly configured to rotate the base relative to the central pulley to move a center point of a support of the first arm and a center point of a support of the second arm along a linear trajectory.

4. The swapper of claim 1, wherein first belt and the second belt each include an in-line tensioner.

5. The swapper of claim 4, wherein at least one of the in-line tensioners includes: a block including a channel, a first block opening, and a second block opening; and a biasing element disposable in the channel, the biasing element including: a first portion including a slot, a second portion including a block fastener opening, and a third portion disposed between the first portion and the second portion, the third portion including a plurality of spring slots, the third portion configured to bias the first portion towards the second portion.

6. A swapper for a cluster tool, comprising: a base including an interior chamber, wherein the base is rotatable about a central axis; a pulley system at least partially disposed in the interior chamber, the pulley system including: a multi-level central pulley, wherein the base is rotatable relative to the multi-level central pulley; a multi-level first elbow pulley rotatable about a first elbow axis; a multi-level second elbow pulley rotatable about a second elbow axis; a first band, wherein a first end of the first band is anchored to a first level of the multi-level central pulley and a second end of the first band is anchored to a first level of the first multi-level elbow pulley; a second band, wherein a first end of the second band is anchored to the first level of the multi-level central pulley and a second end of the second band is anchored to a first level of the second multi-level elbow pulley; a third band, wherein a first end of the third band is anchored to a second level of the multi-level central pulley and a second end of the third band is anchored to a second level of the first multi-level elbow pulley; and a fourth band, wherein a first end of the fourth band is anchored to the second level of the multi-level central pulley and a second end of the fourth band is anchored to a second level of the second multi-level elbow pulley; a first arm rotationally coupled to the first multi-leveled elbow pulley such that rotation of the first multi-leveled elbow pulley rotates the first arm about the first elbow axis; and a second arm rotationally coupled to the second multi-leveled elbow pulley such that rotation of the second multi-leveled elbow pulley rotates the second arm about the second elbow axis.

7. The swapper of claim 6, wherein: the base has a first distance between the central axis and the first elbow axis; and the first arm has a second distance between a central point of a support of the first arm to the first elbow axis, wherein the first distance and the second distance are equivalent distances.

8. The swapper of claim 6, further comprising: a motor assembly configured to rotate the base relative to the central pulley to move a center point of a support of the first arm and a center point of a support of the second arm along a linear trajectory.

9. The swapper of claim 6, wherein: a central point of a support of the first arm is not linearly aligned with the first elbow axis and the central axis when the first arm is in an extended position.

10. The swapper of claim 6, wherein the first band, second band, third band, and fourth band each include an in-line tensioner.

11. The swapper of claim 10, wherein at least one of the in-line tensioners includes: a block including a channel, a first block opening, and a second block opening; and a biasing element disposable in the channel, the biasing element including: a first portion including a slot, a second portion including a block fastener opening, and a third portion disposed between the first portion and the second portion, the third portion including a plurality of spring slots, the third portion configured to bias the first portion towards the second portion.

12. A swapper assembly for a cluster tool, comprising: a housing including a first opening and a second opening; a swapper, the swapper including: a base rotatable relative to the housing about a central axis; a first arm rotationally coupled to the base, wherein the first arm rotates relative to the base about a first elbow axis from a first retracted position to a first extended position, wherein the first arm is partially disposed in the first opening in the first extended position and the first elbow axis is disposed in the housing in the first extended position; and a second arm rotationally coupled to the base, wherein the second arm rotates relative to the base about a second elbow axis from a second retracted position to a second extended position, wherein the second arm is partially disposed in the second opening in the second extended position and the second elbow axis is disposed in the housing in the second extended position.

13. The swapper assembly of claim 12, wherein: the base has a first distance between the central axis and the first elbow axis; and the first arm has a second distance between a central point of a support of the first arm to the first elbow axis, wherein the first distance and the second distance are different distances.

14. The swapper assembly of claim 12, further comprising: a pulley system configured to move the first arm and the second arm.

15. The swapper assembly of claim 12, wherein: the first arm is moveable from the retracted position to a partially extended position along a first trajectory, wherein a center point of a support of the first arm is disposed in the housing when the first arm is in the partially extended position.

16. The swapper assembly of claim 15, wherein the first trajectory is a linear trajectory.

17. The swapper assembly of claim 15, wherein: the first arm is moveable from the partially extended position to the extended position along a second trajectory, wherein the center point passes through the first opening as the first arm moves along the second trajectory.

18. The swapper assembly of claim 12, further comprising: a pulley system disposed in an interior chamber of the base, the pulley system including: a central pulley rotatable relative to the base; a first elbow pulley coupled to the first arm and rotatable about the first elbow axis; a second elbow pulley coupled to the second arm and rotatable about the second elbow axis; at least one of first belts or first bands extending between the first central pulley and the first elbow pulley to rotate the first elbow pulley, and therefore the first arm, about the first elbow axis in response to the rotation of the central pulley; and at least one of second belts or second bands extending between the central pulley and the second elbow pulley to rotate the first elbow pulley, and therefore the second arm, about the second elbow axis in response to the rotation of the central pulley.

19. The swapper assembly of claim 18, wherein the first elbow pulley and the second elbow pulley each have a non-circular profile.

20. The swapper assembly of claim 18, further comprising: a first motor configured to rotate a first shaft coupled to the base, wherein the rotation of the first shaft causes the base to rotate about the central axis; and a second motor configured to rotate a second shaft coupled to the central pulley, wherein the rotation of the second shaft causes the central pulley to rotate about the central axis.