GRAVITY-FED IN-LINE CONTINUOUS PROCESSING SYSTEM AND METHOD

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ABSTRACT

A gravity-fed in-line continuous processing system includes at least one processing chamber disposed between a first load lock and a second load lock. The second load lock is disposed lower than the first load lock. A first device isolates the processing chamber from the first load lock. A second device isolates the processing chamber from the second load lock. There is at least one track through the processing chamber and the first and second load locks. The track is structured and arranged such that an article slides thereon under the force of gravity.
<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>07</td>
<td>Shift</td>
<td>1.2 days</td>
</tr>
<tr>
<td>08</td>
<td>Rotate</td>
<td>3 days</td>
</tr>
<tr>
<td>09</td>
<td>Slide H/L-SP</td>
<td>10 days</td>
</tr>
<tr>
<td>10</td>
<td>Close B</td>
<td>4.2 days</td>
</tr>
<tr>
<td>11</td>
<td>Rotate</td>
<td>3 days</td>
</tr>
<tr>
<td>12</td>
<td>Shift</td>
<td>1.2 days</td>
</tr>
<tr>
<td>13</td>
<td>Vent</td>
<td>10 days</td>
</tr>
<tr>
<td>14</td>
<td>Spreader</td>
<td>45 days</td>
</tr>
<tr>
<td>15</td>
<td>Open C</td>
<td>4.2 days</td>
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<tr>
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<tr>
<td>17</td>
<td>Shift</td>
<td>1.2 days</td>
</tr>
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<td>18</td>
<td>Slide Spreader</td>
<td>10 days</td>
</tr>
<tr>
<td>19</td>
<td>Close C</td>
<td>4.2 days</td>
</tr>
<tr>
<td>20</td>
<td>Rotate</td>
<td>3 days</td>
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<tr>
<td>21</td>
<td>Shift</td>
<td>1.2 days</td>
</tr>
<tr>
<td>22</td>
<td>Vent DLL</td>
<td>10 days</td>
</tr>
<tr>
<td>23</td>
<td>Open D</td>
<td>4.2 days</td>
</tr>
<tr>
<td>24</td>
<td>Shift</td>
<td>1.2 days</td>
</tr>
<tr>
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<td>Slide DLL-E</td>
<td>10 days</td>
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<td>4.2 days</td>
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<tr>
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<td>3 days</td>
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<td>Rough DLL</td>
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<tr>
<td>31</td>
<td>Cycle</td>
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**FIG. 7A, Sheet3**
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<tr>
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<tr>
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<td>S</td>
<td>45 days</td>
</tr>
<tr>
<td>189</td>
<td>O</td>
<td>4.2 days</td>
</tr>
<tr>
<td>190</td>
<td>3 days</td>
<td></td>
</tr>
<tr>
<td>191</td>
<td>1.2 days</td>
<td></td>
</tr>
<tr>
<td>192</td>
<td>S</td>
<td>10 days</td>
</tr>
<tr>
<td>193</td>
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<td>4.2 days</td>
</tr>
<tr>
<td>194</td>
<td>3 days</td>
<td></td>
</tr>
<tr>
<td>195</td>
<td>1.2 days</td>
<td></td>
</tr>
<tr>
<td>196</td>
<td>V</td>
<td>10 days</td>
</tr>
<tr>
<td>197</td>
<td>O</td>
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<tr>
<td>200</td>
<td>S</td>
<td>10 days</td>
</tr>
<tr>
<td>201</td>
<td>C</td>
<td>4.2 days</td>
</tr>
<tr>
<td>202</td>
<td>3 days</td>
<td></td>
</tr>
<tr>
<td>203</td>
<td>1.2 days</td>
<td></td>
</tr>
<tr>
<td>204</td>
<td>40 days</td>
<td></td>
</tr>
</tbody>
</table>

FIG. 7B, Sheet3
FIG. 10.
FIG. 11.
GRAVITY-FED IN-LINE CONTINUOUS PROCESSING SYSTEM AND METHOD

RELATED APPLICATIONS

[0001] This application is a Continuation of prior U.S. patent application Ser. No. 10/400,775 filed Mar. 27, 2003 which claims priority of and is related to U.S. Provisional Patent Application Serial No. 60/368,818, filed Mar. 29, 2002. This application is also related to the U.S. patent application entitled ROTARY BARREL GATE VALVE, filed on even date herewith and hereby incorporated by reference herein, and which also claims priority to U.S. Provisional Patent Application Serial No. 60/368,818 filed Mar. 29, 2002.

FIELD OF THE INVENTION

[0002] This invention relates to a gravity-fed in-line processing system useful for, inter alia, rapidly coating plastic substrates such as plastic flatware and cellular telephone housings.

BACKGROUND OF THE INVENTION

[0003] Conventional systems and methods of applying coatings to substrates such as metallizing insulative substrates include electroplating, electroless plating, painting, arc-spray, evaporative vacuum metallization, and sputter vacuum metallization. These systems and processes are usually batch oriented. Typical batch oriented systems require parts or substrates to be placed on racks for insertion into a batch chamber. The batch chamber door is opened, a rack of parts is inserted into the chamber, and the door is then closed and sealed. Thereafter, coating takes place, and after coating, the batch chamber door is again opened, and the rack of parts is removed manually and unloaded.

[0004] One disadvantage of batch oriented production systems is that during the coating process, other operations cease, creating down time. Also, the cycle time is long, and large production run volumes are required for the system to be cost effective. Batch oriented systems result in large work-in-process inventories and a large number of at-risk parts before process quality can be assessed.

[0005] Some of these disadvantages and limitations may be overcome by so-called “in-line” systems that integrate vacuum metallization “in-line” with a parts molding machine. However, conventional systems are often expensive and complex. Moreover, such systems often include conveyors, robot arms within the system, and/or gates with valves and seals that utilize up and down and/or sliding motion which are subject to excess wear, malfunction and necessitate frequent replacement of parts over the life of the system. The conveyors, and robot arms within the system, can also contaminate the highly sensitive vacuum chambers.

BRIEF SUMMARY OF THE INVENTION

[0006] It is therefore an object of this invention to provide an improved system for applying coatings to substrates and particularly for metallizing plastic parts.

[0007] It is a further object of this invention to provide a truly in-line metallizing system that may be physically located adjacent a parts molding machine.

[0008] It is a further object of this invention to provide such a system that is rapid, automated, and continuous, with reduced cycle time and reduced down time.

[0009] It is a further object of this invention to provide such a system which eliminates the need for a conveyor or a robot arm within the system.

[0010] It is a further object of this invention to provide such a system with improved and more robust gates or valves.

[0011] This invention results from the realization that an improved, faster, more robust, higher quality and more reliable in-line metallization processing system can be achieved with a system that utilizes gravity instead of mechanical conveyors, or robot arms within, and which utilizes rotary barrel gate valves in place of conventional gates and valves, and which may be located adjacent a molding machine.

[0012] This invention features a gravity-fed in-line continuous processing system including at least one processing chamber disposed between a first load lock and a second load lock, with the second load lock disposed lower than the first load lock. The system may include a first device for isolating the processing chamber from the first load lock, a second device for isolating the processing chamber from the second load lock, and at least one track through the processing chamber and the first and second load locks, with the track structured and arranged such that an article slides thereon under the force of gravity.

[0013] In one embodiment, the processing chamber, the first load lock and the second load lock may all be angled with respect to the horizontal, or the track may be angled with respect to the horizontal. The track, the processing chamber, the first load lock and the second load lock, or any combination thereof, may be angled with respect to the horizontal. The angle with respect to the horizontal may be greater than 33° but less than 43°. The angle with respect to the horizontal may be about 40°. The first load lock may be an input load lock, and the second load lock may be an output load lock. The first device may be structured and arranged to prevent the article from sliding under the force of gravity when the first device is closed. The second device may be structured and arranged to prevent the article from sliding under the force of gravity when the second device is closed. The first device may be structured and arranged to allow the article to slide on the track from the first load lock to the processing chamber when the first device is open. The second device may be structured and arranged to allow the article to slide on the track from the processing chamber to the second load lock when the second device is open.

[0014] The first device may be a first rotary barrel gate valve and the second device may be a second rotary barrel gate valve. The system may include a plurality of tracks through the processing chamber and the first and second load locks, and all tracks may be angled with respect to the horizontal. The plurality of tracks may be structured and arranged such that articles in each of the plurality of tracks slide thereon under the force of gravity for simultaneously processing a plurality of articles. The plurality of tracks are typically parallel to one another and the parallel tracks of the first load lock, the tracks of the processing chamber, and the tracks of the second load lock are aligned with one another.
The system may include an input tray disposed adjacent the first load lock. An output tray may be disposed adjacent the output load lock. The processing chamber may be a vacuum sputtering chamber. The first load lock and the second load lock may be structured and arranged for venting from a first pressure to a second pressure. The first pressure may be a vacuum and the second pressure may be atmospheric pressure. The first load lock and the second load lock may be structured and arranged for evacuating from a first pressure to a second pressure. The first pressure may be atmospheric pressure and the second pressure may be a vacuum. The system may include a third device between the first load lock and atmosphere and a fourth device between the second load lock and atmosphere. The third device may be a third rotary barrel gate valve and the fourth device may be a fourth rotary barrel gate valve. The article to be processed may be any sputterable part such as plastic, polystyrene, and in particular it may be polystyrene plastic cutlery. The system may further include a take-out robot for transferring articles from an injection molding machine to the input tray. The first load lock, the second load lock, the first device, the second device and the processing chamber may be sequenced such that sets of articles may be processed simultaneously. Each of the processing chamber, the first and second load locks and the first and second devices may be angled with respect to the horizontal. The first device may include a body, at least one passage through the body defining an inlet and an outlet, a first actuator for rotating the body, a second actuator for translating the body, and a sealing portion on the body for sealing the body with respect to an opening into a chamber adjacent the body.

This invention further features a gravity-fed in-line continuous processing system including at least one processing chamber disposed between a first load lock and a second load lock, the second load lock disposed lower than the first load lock, a device for isolating the processing chamber from the first load lock and a second device for isolating the processing chamber from the second load lock. The processing chamber, the first load lock, the second load lock, the first device and the second device may all be angled with respect to the horizontal, each having a plurality of tracks with the plurality of tracks structured and arranged such that a plurality of articles slide thereon under the force of gravity from the first load lock, through the processing chamber, and to the second load lock.

This invention further features a gravity-fed in-line continuous processing system including at least one vacuum sputtering chamber disposed between a first load lock and a second load lock, the second load lock disposed lower than the first load lock. A first rotary barrel gate valve for isolating the vacuum sputtering chamber from the first load lock may be included, the first rotary barrel gate valve structured and arranged to prevent an article from sliding under the force of gravity when the first rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the first rotary barrel gate valve is open. A second rotary barrel gate valve for isolating the vacuum sputtering chamber from the second load lock may be included, the second rotary barrel gate valve structured and arranged to prevent an article from sliding under the force of gravity when the second rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the second rotary barrel gate valve is open.

This invention also features a gravity-fed in-line continuous processing system including at least one processing chamber disposed between a first load lock and a second load lock, the second load lock disposed lower than the first load lock. There may be included a first rotary barrel gate valve for isolating the processing chamber from the first load lock, the first rotary barrel gate valve structured and arranged to prevent an article from sliding under the force of gravity when the first rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the first rotary barrel gate valve is open. There may be included a second rotary barrel gate valve for isolating the processing chamber from the second load lock, the second rotary barrel gate valve structured and arranged to prevent the article from sliding under the force of gravity when the second rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the second rotary barrel gate valve is open. There may further be included a third rotary barrel gate valve for isolating the first load lock from atmosphere, the third rotary barrel gate valve structured and arranged to prevent the article from sliding under the force of gravity when the third rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the third rotary barrel gate valve is open. An input tray may terminate at the third rotary barrel gate valve. A fourth rotary barrel gate valve may be included for isolating the second load lock from atmosphere, the fourth rotary barrel gate valve structured and arranged to prevent the article from sliding under the force of gravity when the fourth rotary barrel gate valve is closed and to allow the article to slide therethrough under the force of gravity when the fourth rotary barrel gate valve is open. An output tray may be adjacent the fourth rotary barrel gate valve, and a plurality of tracks may be angled through the first load lock, the processing chamber, and the second load lock interconnecting the input tray and the output tray to urge, under the force of gravity, articles through the first load lock, the processing chamber, and the second load lock.

This invention also features a gravity-fed in-line continuous processing system including at least one processing chamber module disposed between a first load lock module and a second load lock module, the second load lock module disposed lower than the first load lock module. A first device may be included for isolating the processing chamber module from the first load lock module, a second device may be included for isolating the processing chamber module from the second load lock module, and there may be at least one track through the processing chamber module and the first and second load lock modules, the track structured and arranged such that an article slides thereon under the force of gravity.

This invention further features a gravity-fed in-line continuous processing system including at least one processing chamber including at least one track therethrough, with the track structured and arranged such that an article slides thereon under the force of gravity. The processing chamber may be angled with respect to the horizontal and the at least one track may be angled with respect to the horizontal.

This invention further features a gravity-fed in-line continuous processing system including means for processing disposed between a first means for alternating between a first pressure and a second pressure, and a second means
for alternating between a first pressure and a second pressure. The first pressure may be atmospheric pressure and the second pressure may be a vacuum. Alternatively, the first pressure may be a vacuum and the second pressure may be atmospheric pressure. The second means for alternating may be disposed lower than the first means for alternating. There may be a first means for isolating the means for processing from the first means for alternating and a second means for isolating the means for processing from the second means for alternating. The system may further include at least one track through the means for processing and the first and second means for alternating. The track may be structured and arranged such that an article slides thereon under the force of gravity.

[0024] This invention further features a method for coating substrates, the method comprising providing at least one processing chamber and disposing the processing chamber between a first load lock and a second load lock. The second load lock may be disposed lower than the first load lock. The method further includes isolating the processing chamber from the first load lock with a first device, isolating the processing chamber from the second load lock with a second device, and providing at least one track through the processing chamber and the first and second load locks and structuring and arranging the track such that an article slides thereon under the force of gravity. The method may further include the step of angling the processing chamber, the first load lock and the second load lock with respect to the horizontal. The angle with respect to the horizontal may be greater than 330° but less than 43°. The angle with respect to the horizontal may be about 40°. The method may further include angling the at least one track with respect to the horizontal. The first load lock may be an input load lock and the second load lock may be an output load lock. The step of isolating the processing chamber from the first load lock may be carried out by a first device, and the step of isolating the processing chamber from the second load lock may be carried out by a second device. The first and second devices may be rotary barrel gate valves.

[0025] The method may further include structuring and arranging the first device and the second device to prevent the article from sliding under the force of gravity when the first device is closed. The method of this invention may further include structuring and arranging the first and second devices to allow the article to slide on the track from the first load lock to the processing chamber when the first device is open. The first device may be a first rotary barrel gate valve and the second device may be a second rotary barrel gate valve. The method may further include the steps of providing a plurality of tracks through the processing chamber and the first and second load locks, angling all tracks with respect to the horizontal, and structuring and arranging each of the plurality of tracks such that articles in each of the plurality of tracks slide thereon under the force of gravity for simultaneously processing a plurality of articles. The plurality of tracks may be parallel to one another. The method may further include the steps of aligning the parallel tracks of the first load lock, the tracks of the processing chamber, and the tracks of the second load lock with one another, disposing an input tray adjacent the first load lock, and disposing an output tray adjacent the output load lock. The method may further include structuring and arranging the first load lock and the second load lock for alternating between a first pressure and a second pressure. The first pressure may be a vacuum and the second pressure may be atmospheric pressure. The method may also include providing a third device between the first load lock and atmosphere and a fourth device between the second load lock and atmosphere, where the third device is a third rotary barrel gate valve and the fourth device is a fourth rotary barrel gate valve. The method further include sequencing the first load lock, the second load lock, the first device, the second device and the processing chamber such that sets of articles may be processed simultaneously.

[0023] This invention also features a gravity-fed in-line continuous processing system including at least one processing chamber isolatable with respect to first and second chambers and means for urging an article from the first chamber, through the processing chamber, and to the second chamber under the force of gravity.
BRIEF DESCRIPTION OF THE DRAWINGS

[0026] Other objects, features and advantages will occur to those skilled in the art from the following description of a preferred embodiment and the accompanying drawings, in which:

[0027] FIG. 1 is a schematic side view of one preferred embodiment of the gravity-fed in-line continuous processing system of this invention;

[0028] FIG. 2 is a schematic cross-sectional side view of the load locks and processing chamber of the system shown in FIG. 1;

[0029] FIG. 3 is a schematic cross-sectional side view of rotary barrel gate valves useful in connection with the gravity-fed in-line continuous processing system of this invention;

[0030] FIG. 4 is a schematic top view of a gravity-fed in-line continuous processing system in accordance with the present invention showing the tracks of each section;

[0031] FIG. 5 is a three-dimensional view of tracks useful in accordance with the present invention;

[0032] FIG. 6 is a schematic side view of the gravity-fed in-line continuous processing system shown in FIG. 1 in conjunction with an injection molding machine and a take-out robot;

[0033] FIGS. 7A and 7B are a sequencing chart showing cycle times and sequencing for the system shown FIG. 6;

[0034] FIG. 8 is a schematic three-dimensional front view of a gravity-fed in-line continuous processing system of this invention;

[0035] FIG. 9 is a schematic cross-sectional side view of one embodiment of a rotary barrel gate valve for use with the system of this invention;

[0036] FIG. 10 is a schematic side view of one portion of the rotary barrel gate valve of FIG. 9;

[0037] FIG. 11 is a schematic cross-sectional view of the rotary barrel gate valve of FIG. 9 shown in the open position;

[0038] FIG. 12 is a schematic cross-sectional view of a rotary barrel gate valve of FIG. 9 shown in the closed position;

[0039] FIG. 13 is an enlarged schematic cross-sectional side view of the sealing portion of the rotary barrel gate valve;

[0040] FIG. 14 is a schematic cross-sectional view of an actuator for translating the rotary barrel gate valve; and

[0041] FIG. 15 is a schematic cross-sectional view of an actuator for rotating the rotary barrel gate valve.

DISCLOSURE OF THE PREFERRED EMBODIMENT

[0042] Aside from the preferred embodiment or embodiments disclosed below, this invention is capable of other embodiments and of being practiced or being carried out in various ways. Thus, it is to be understood that the invention is not limited in its application to the details of construction and the arrangements of components set forth in the following description or illustrated in the drawings.

[0043] One gravity-fed in-line continuous processing system in accordance with the present invention is shown in FIG. 1. The system is comprised of modules, for example, a first load lock with gate valves module, a processing chamber module, and a second load lock with gate valves module. Parts for processing proceed from one module to another module by gravity, with the parts guided individually in tracks or chutes. Load-locks with rotary barrel gate valves preferably function as sealing mechanisms and as part escapements, controlling the flow of parts from one machine module to the next.

[0044] One embodiment of this invention system 10, FIG. 1 includes at least one means for processing, such as processing chamber or module 12. Processing chamber 12 is disposed between first means for alternating between a first and a second pressure, such as first load lock or module 14, and second means for alternating between a first and a second pressure, such as second load lock or module 16, with second load lock 16 disposed lower than first load lock 14. In accordance with a preferred embodiment of this invention, first load lock 14 is an input load lock, and second load lock 16 is an output load lock, as shown in FIGS. 1 and 2. As it is known in the art, load lock pressure alternates from high pressure to low pressure and vice versa, depending on the stage in a process.

[0045] Any combination of processing chamber modules and a load lock modules may be used with the system of the subject invention, thus providing flexibility for the system user. For example, the system may include a series of load locks and processing chambers in order to end up with a thicker part coating than could be achieved with only one processing chamber and using conventional coating methods.

[0046] System 10, FIG. 1 further includes first means for isolating, such as first device 18, for isolating processing chamber 12 from first load lock 14, and second means for isolating, such as second device 20, for isolating processing chamber 12 from second load lock 16. First load lock 14 and second load lock 16 are structured and arranged for venting or evacuating from a first to a second pressure by venting or evacuating load locks 14 and 16, from a vacuum to ambient atmospheric pressure and vice versa in one example, using known methods. For example, when article 24 is in first load lock 14 at ambient atmosphere, before article 24 can enter into processing chamber 12, first load lock 14 is evacuated. Then later, before first load lock can be opened to allow in the next article, load lock 14 must be vented.

[0047] System 10 includes at least one track or chute 22 through at least one of processing chamber 12 and first and second load locks 14 and 16, with track 22 structured and arranged such that article or part 24 slides on track 22 under the force of gravity. Track 22 is shown in phantom cross-section and in exemplary fashion in first load lock 14 of FIG. 1. At least one of processing chamber 12, first load lock 14, second load lock 16, first device 18 and second device 20, is angled with respect to horizontal 19. Alternatively or additionally, track 22 may be angled with respect to horizontal 19. In one embodiment system 10 is designed for coating plastic flatware or cutlery, and angle 26 is greater than about 32° but less than about 44°. In one embodiment
for coating plastic flatware, angle 26 is about 40°. Optimum angles for various coating processes, such as coating phone carriers, or for tracks or chutes that include bearings, are possible with system 10. It can be seen that a combination of angling track 22 and modules 12, 14 and/or 16 with respect to the horizontal can achieve a desired angle for the system. Track or chute 22 is structured and arranged so that part 24 will slide under its own weight, eliminating the need for complex conveyors and robotic arms within the system, thus improving overall system mechanical and operational reliability. There is typically one part 24 per chute 22 within any particular module, although there may be many chutes within any particular module, as well as sets of articles passing through the system at one time as described below with respect to sequencing of the system.

[0048] In one embodiment, processing chamber 12 is a vacuum sputtering chamber including a cathode and shield assembly for metallization on at least one side of article 24 as is known to those skilled in the art, although the processing chamber 12 of this invention is not limited to a vacuum sputtering chamber or to a particular coating or to coating on one side only. Article 24 to be coated may be any sputterable part, such as plastic or polystyrene. The present invention has been successfully used to coat or metallize polystyrene plastic cutlery, such as spoons, knives, and forks, with stainless steel. The system of the present invention may further include input tray 40 and output tray 42 as shown in FIG. 1.

[0049] When first device 18 is closed, FIG. 3, first device 18 is structured and arranged to prevent article 24(1) from sliding under the force of gravity. Similarly, when second device 20 is closed, second device 20 is structured and arranged to prevent article 24(2) from sliding under the force of gravity (not shown). Conversely, when second device 20 is open, second device 20 is structured and arranged to allow article 24(2) to slide under the force of gravity on track 22 through second device 20 and into the next chamber or to atmosphere. Similarly, when first device 18 is open, first device 18 is structured and arranged to allow article 24(1) to slide on track 22 through first device 18 and into the next chamber or to atmosphere (not shown). Part gate 29 may be used at any point or in any module of the system, even in addition to the article stopping function of first and second devices 18 and 20.

[0050] In one preferred embodiment, first and second devices 18 and 20 are rotary barrel gate valves as shown in FIGS. 2 and 3. First and second devices 18 and 20, i.e. rotary barrel gate valves 18 and 20, are used to open and close first and second load locks 14 and 16 to either the atmosphere or to processing chamber 12. For example, a mechanical roughing pump may be used to evacuate first load lock 14 from a first pressure, typically atmosphere, prior to transferring part 24 from first load lock 14 into processing chamber 12 which is at a second pressure, typically a vacuum.

[0051] First and second devices 18 and 20 (i.e. rotary barrel gate valves) operate with long durability and with high reliability. Each gate valve is interlocked or sequenced to detect full closure, minimizing the risk of direct passing of atmosphere into processing chamber 12, for example, should part 24 become lodged in a gate valve. If part 24 does not get lodged in this manner, system 10 halts and an error condition is reported indicating the reason for the error.

[0052] In accordance with one embodiment of the present invention, system 10 may include third device 18', FIGS. 1 and 2 between first load lock 14 and atmosphere, and fourth device 20' between second load lock 16 and atmosphere, where atmosphere is atmospheric pressure. Third and fourth devices 18' and 20' may be rotary barrel gate valves similar to first and second devices 18 and 20.

[0053] Each of processing chamber 12, first and second load locks 14, 16, and first and second devices 18, 20 may include at least one track 22. Each of processing chamber 12, first and second load locks 14 and 16, and first and second devices 18 and 20 may include a plurality of tracks 22a, 22b, . . . , 22n, FIG. 4. In one example, plurality of tracks 22a, 22b, . . . , 22n are angled with the horizontal in like manner as single track 22 in FIG. 1. The plurality of tracks 22a, 22b, . . . , 22n are structured and arranged such that articles 24a, 24b, . . . , 24n each in each of plurality of tracks 22a, 22b . . . , 22n slide therein under the force of gravity for simultaneous processing.

[0054] Tracks 22a, 22b, . . . , 22n of first load lock 14, corresponding tracks, i.e. 22a', 22b', . . . , 22n' of processing chamber 12 and corresponding tracks i.e. 22a", 22b", . . . , 22n" of second load lock 16 are aligned with one another. Each of tracks 22a, 22b . . . , 22n, are parallel to one another, as are each of tracks 22a', 22b', . . . , 22n' and each of tracks 22a", 22b", . . . , 22n". The parallel layout of the tracks permits more tracks to be added by adding width to system 10, and by adding length to the first and second devices 18, 20 (and third and fourth devices 18', 20') under the condition, noted above, both first and second devices 18, 20 also include tracks, i.e. 22a"", 22b"", . . . , 22n"", (not shown) corresponding to and aligned with tracks of adjacent load locks or processing chamber.

[0055] Tracks 22a, 22b . . . , 22n are arranged in groups 70, 72, 74, 76 . . . with members 80, 82, 84 . . . 84n installed between groups to provide structural support, as exemplified by FIG. 5 showing the tracks of input tray 40. In one embodiment, members 80 and tracks 22a, 22b . . . , 22n are machined from one solid sheet of aluminum. Input tray 40 includes tracks, i.e. 22a", 22b", . . . , 22n" corresponding to the tracks 22a, 22b . . . , 22n of input load lock 14, tracks 22a', 22b', . . . , 22n' of processing chamber 12, tracks 22a", 22b", . . . , 22n" of output load lock 16 as shown in FIG. 4, and so on with respect to the tracks of first and second devices 18, 20 and output tray 42 (not shown).

[0056] Those skilled in the art will recognize that a system in accordance with the present invention may be comprised of processing chamber 12 alone including at least one track, if contamination during processing is not a concern. In such a case, processing chamber 12 may be angled with respect to the horizontal, or track 22 may be angled with respect to the horizontal, or both processing chamber 12 and track 22 may be angled with the horizontal.

[0057] Gravity-fed in-line continuous processing system 10 of this invention, FIG. 6 may be used stand-alone, or it may include interface 50 with injection molding machine 52, with interface 50 being an electrical handshake scheme as is known in the art. The system may further include take-out robot 54 for transferring parts or articles 24a, 24b . . . 24n, FIG. 4 from injection molding machine 52 to input
tray 40, **FIG. 6.** Parts 24a, 24b . . . 24n are loaded onto input tray 40 by take out robot 54. Input tray 40 may accept parts from take out robot 54 and laterally shift parts 24 to align them to tracks 22a, 22b . . . 22n. Optical systems can be used to determine if the tray is full.

[0058] Applying a metal coating to a clear polystyrene cutlery, for example, by metallization, can be accomplished in a vastly improved manner utilizing this invention. The invention assures high quality, high adhesion, and an overall more robust process.

[0059] The operation of system 10 and method of the invention is described as follows. Folded molten parts or articles 24a, 24b . . . 24n (not shown) are placed on input tray 40 by takeout robot 54, **FIG. 6.** In one example of this invention, forty parts (e.g. 24a, 24b . . . 24n where part 24n is the fortieth part 24n) are transferred at a time from input tray 40 to first or input load lock 14 through rotary barrel gate valve 18. Thereafter air is evacuated from input load lock 14. From input load lock 14 parts 24a, 24b . . . 24n are transferred through rotary barrel gate valve 18 into processing or sputtering chamber 12 where they are sputtered or coated. In this example, parts 24a, 24b . . . 24n are thereafter transferred through rotary barrel gate valve 20 into second or output load lock 16. Output load lock 16 is then vented to atmospheric pressure, and parts 24a, 24b . . . 24n are thereafter transferred through rotary barrel gate valve 20 to output tray 42 where parts 24a, 24b . . . 24n may be transferred into boxes 60 for shipping. The entire machine cycle may take place in seconds, in contrast to current systems which take much longer. The subject invention thus results in an improved, more rapid, gravity-fed in-line continuous processing system.

[0060] Notably, in accordance with the present invention, all portions of system 10, namely rotary barrel gate valve 18, input load lock 14, rotary barrel gate valve 18, processing chamber 12, rotary barrel gate valve 20, output load lock 16, and rotary barrel gate valve 20 are interlocked or sequenced such that sets of articles may be processed simultaneously. This makes the system more efficient and continuous.

[0061] Particularly, one sequence for use in system 10 is shown in **FIGS. 7A and 7B,** where “A” is rotary barrel gate valve 18 of **FIG. 6.** “B” is rotary barrel gate valve 18, “C” is rotary barrel gate valve 20, and “D” is rotary barrel gate valve 20. One “day” in **FIGS. 7A and 7B** is equivalent to 100 milliseconds. Input load lock 14 and output load lock 16 are signified by “ILL,” and “OLL” in **FIGS. 7A and 7B.** In **FIGS. 7A and 7B,** reference numerals 300a . . . 300n each represent one set of parts or articles 24a . . . 24n through system 10. First set 300a represents the first set of parts or articles to go through the system, and 300b represents a second set of parts to go through the system. The start of second set of parts 300b is determined by the existence of proper conditions downstream in system 10. For example, opening of rotary barrel gate valve 18 for second set of parts 300b is determined by proper completion of the load lock cycle for first set of parts 300a. Controller 90, **FIG. 6** controls the sequencing of the system using standard customizable software, such as Ladder Logic, which is standard for use with automatic Programmable Logic Controllers (PLCs).

[0062] In one example, the opening of rotary barrel gate valve 18, **FIG. 6** for the start of a second cycle 302, **FIGS. 7A and 7B** of parts begins when first set of parts 300a are being processed or sputtered 304 in processing chamber 12, **FIG. 6.** As shown in **FIGS. 6, 7A and 7B,** at that point in time, rotary barrel gate valve 18 is opened (unsealed) to allow second set of parts 300b to slide through into input load lock 14. Input load lock 14 is sealed by closing rotary barrel gate valve 18. Input load lock 14 is evacuated from atmospheric pressure of approximately 760 Torr to vacuum pressure of approximately 250 milliTorr. Rotary barrel gate valve 18 is opened and first set of parts 300b slides into chamber 12. Rotary barrel gate valve 18 is then closed, input load lock 14 is vented to atmospheric pressure, and first set of parts 300a is sputtered. During this time, rotary barrel gate valve 18 opens again and second set of parts 300b enters input load lock 14. Rotary barrel gate valve 18 closes and seals, and rotary barrel gate valve 20 is opened while input load lock 14 (with second set of parts 300b) is being evacuated. First set of parts 300a slide from processing chamber 12 to output load lock 16. When input load lock 14 is evacuated, output load lock 16 is vented to atmosphere. Second set of parts 300b thereafter slides from input load lock 14 into processing chamber 12 after rotary barrel gate valve 18 opens. First set of parts 300a slides from output load lock 16 to an optional output tray after rotary barrel gate valve 20 opens. This sequence continues and repeats itself for any number of desired cycles or sets of parts 300a . . . 300n. In one embodiment, the direction of sealing of rotary gate valves 18 and 20, **FIG. 6** is such that the sealing of chamber 12 occurs at points 80, 82, 84, 86 in order to take advantage of pressure assisted sealing. Pressure assisted sealing is desirable for longer rotary barrel gate valves 18, 18, 20, 20 where there is deflection of the rotary barrel gate valves due to their length. Sealing points 80, 82, 84 and 86 result in load locks 14 and 16 having larger volumes. In other embodiments where pressure assisted sealing is less important or not desired, such as embodiments with short rotary barrel gate valves 18, 18, 20, 20, sealing of chamber 12 could occur at points 85 and 87 instead of or in addition to points 82 and 84, for example. This would result in load locks 14 and 16 having smaller volumes, which may be desirable in some applications of system 10.

[0063] The sequence just described is for system 10, **FIG. 6** using a thin coating metalizer for processing chamber 12 and using only one vacuum pump for both first and second load locks 14 and 16. It will be apparent to one skilled in the art that the sequencing may be adjusted to accommodate various processing times, any number of chambers and load locks, and for any number of vacuum pumps used with the system.

[0064] A schematic three-dimensional representation of system 10 of the invention, without take out robot or output tray, is shown in **FIG. 8.**

[0065] For system 10 of this invention, it is useful to use first, second, third and fourth devices 18, 18', 20', 20, **FIG. 6** which are rotary barrel gate valves, represented as rotary barrel gate valve 100 in **FIGS. 9-13.**

[0066] Rotary barrel gate valve 100 includes body 102, **FIGS. 9 and 10** and at least one passage 104 through body 102 defining inlet 106 and outlet 108. Means for rotating body 102, such as actuator 110, rotates body 102 about its axis 105, i.e. in the directions of arrow 111. Means for translating or moving body 102, such as actuator 112,
translates or moves body 102 approximately linearly, i.e. in the directions of arrow 113. Means for sealing, such as sealing portion 116 on body 102, FIG. 10 is for sealing body 102 with respect to an opening into a chamber adjacent body 102 (adjacent chamber not shown). In one example, body 102 is cylindrical and solid, and passage 104 through body 102 has an circular shape. If rotary barrel gate valve 100 is adjacent a vacuum chamber, body 102 is typically surrounded by housing 129 as shown in FIG. 9. Body 102, however, could be hollow and passage 104 could be in the form of a track interconnecting an inlet and an outlet as shown in FIG. 10.

[0067] Passage 104 includes at least one track or chute 120. In one embodiment, a plurality of passages 104, 104a . . . 104n defines a plurality of inlets 106, 106a . . . 106n and outlets 108, 108a . . . 108n. Each of the plurality of passages 104, 104a . . . 104n includes at least one track or chute 120 therein, and each passage 104, 104a . . . 104n includes a plurality of tracks or chutes 120, 120a, . . . 120n, 120a, . . . 120n. Such an embodiment also includes a plurality of sealing portions 116. 116a . . . 116n. FIG. 10. By adding length and additional passages, rotary barrel gate valve 100 of this invention is scalable. This results in decreased cost to add to system capacity, because adding length and increasing the number of passages 104 to body 102 does not require any significant changes to actuator 110 or 112.

[0068] In one embodiment, sealing portion 116, FIG. 10 which may be anywhere on body 102, is O-ring 130 disposed in groove 132 formed on surface 138 of body 102. In one preferred embodiment, body 102 will have passage 104 corresponding to sealing portion 116 such that when body 102 is rotated as indicated by arrow 111, passage 104 and sealing portion 116 will alternately be aligned with an opening into a chamber adjacent the body (not shown). In other embodiments, O-ring 130 may instead be located about the opening into an adjacent chamber (not shown). In either embodiment, the O-ring pushes on and off the sealing surface, maximizing the life of the surface of the O-ring.

[0069] When rotary barrel gate valve 100 is open, FIG. 11 inlet 106 in passage 104 of body 102 is aligned with opening 140 of chamber 12, allowing article 24, for example, to move from chamber 12 to output load lock 16. Controller 300 may be included for interlocking or sequencing each gate valve 100 with any other gate valves in accordance with system 10 to detect full closure and to allow for processing of a plurality of articles simultaneously in one track. Thus, for instance, the risk of direct passing of atmosphere into a processing chamber 12 is minimized should an article become lodged in any gate valve. In such an event, system 10 halts and an error condition is reported. Also, sequencing of multiple rotary barrel gate valves increases productivity.

[0070] Rotary barrel gate valve 100 is moved from closed, FIG. 12, to open, FIG. 11, and vice versa, by actuators 110 and 112, FIG. 9. When rotary barrel gate valve 100 is open as in FIG. 11, inlet 106 is aligned with opening 140 into chamber 12. Passage 104 now provides access through rotary barrel gate valve 100 out of chamber 12. To close rotary barrel gate valve 100, actuator 110, FIG. 9 rotates body 102 in the direction of arrow 150, FIG. 11 to align sealing portion 116 with opening 140. Now, passage 104, FIG. 12 is not aligned with opening 140. Immediately thereafter, actuator 112, FIG. 9 moves or translates sealing portion 116 in the direction of arrow 152 and against opening 140. Then, to open rotary barrel gate valve 100, actuator 112 moves sealing portion 116 in the direction of arrow 154 and immediately thereafter actuator 110 rotates body 102 in the direction of arrow 156 to once again align inlet 106 with opening 140 into chamber 12.

[0071] When rotary barrel gate valve 100 is closed, FIG. 13 groove 132 is located in opposing flats 134, 136 formed on surface 138 of body 102. In one embodiment, portion or nose piece 142 of body 102 projects between opposing flats 134, 136 and may have a curvature to form article stopping surface or escavement 144 for stopping article 24, for example, from output load lock 16 to atmosphere. Conversely, when rotary barrel gate valve 100 is open, portion 142 of body 102 no longer forms article stopping surface 144. In one embodiment of system 10, article stopping surface 144 formed by portion 142 is used only in rotary barrel gate valve 20, FIG. 1, with backs 60, 62, and 64 of rotary barrel gate valves 18, 18' and 20 serving to stop article 24. Whether by article stopping surface 144 or by backs 60, 62, 64, rotary barrel gate valves 18, 18', 20 are structured and arranged to prevent article 24 from sliding under the force of gravity when closed.

[0072] As described herein, a “chamber” could be an input load lock or an output load lock or atmosphere, and the term “chamber” as used herein is not necessarily limited to a processing chamber. For example, in FIG. 12, rotary barrel gate valve 100 seals chamber 12, e.g. a processing chamber, with respect to output load lock 16. However, in another example, rotary barrel gate valve 18', FIG. 1 seals input load lock “chamber”14 from atmosphere.

[0073] For use with rotary barrel gate valve 100 actuator 110, FIG. 14 may be a pneumatic rotary actuator or a cam rotary actuator. In one embodiment, actuator 110 is a servo motor connected to body 102 for rotating body 102. Actuator 110 alternately rotates body 102 to align sealing portion 116, FIGS. 12 and 13 with, for example, opening 140 into chamber 12, and to align passage 104 with opening 140 into chamber 12. Actuator 112, FIG. 15 is typically a pneumatic cylinder 200. When activated, pneumatic cylinder 200 of actuator 112 projects (or retracts) push pin 202 which causes body 102 to pivot around pivot point 204 in the directions of arrow 206, thus urging or translating body 102 approximately linearly, for example, toward and away from chamber 12, as shown in FIGS. 12 and 13. In this embodiment, body 102 moves approximately linearly but in a very slight arc. Actuator 112 may utilize a lead screw or other mechanical device for linear translation (not shown). The servo motor and the short stroke of actuator 112 permit very fast gate valve opening and closing times.

[0074] As noted, the number of chambers or modules of system 10 in accordance with this invention may be increased or decreased and articles other than plastic cutlery may be coated. Other types of processing chambers may be used or added to the system. Also, other types of load and unload locks may be used.

[0075] Although specific features of the invention are shown in some drawings and not in others, this is for convenience only as each feature may be combined with any or all of the other features in accordance with the invention. The words “including”, “comprising”, “having”, and “with”
as used herein are to be interpreted broadly and comprehensively and are not limited to any physical interconnection. Moreover, any embodiments disclosed in the subject application are not to be taken as the only possible embodiments.

[0076] Other embodiments will occur to those skilled in the art and are within the following claims:

What is claimed is:

1. A gravity-fed in-line continuous processing system comprising:
   at least one processing chamber disposed between a first load lock and a second load lock, the second load lock disposed lower than the first load lock;
   a first device including a body for isolating the processing chamber from the first load lock;
   a second device for isolating the processing chamber from the second load lock;
   at least one track through the processing chamber and the first and second load locks, the track structured and arranged such that an article slides thereon under the force of gravity; and
   at least one passage through the body defining an inlet and an outlet, a first actuator for rotating the body, a second actuator for translating the body, and a sealing portion on the body for sealing the body with respect to an opening into a chamber adjacent the body.

2. A gravity-fed in-line continuous processing system comprising:
   at least one processing chamber disposed between a first load lock and a second load lock, the second load lock disposed lower than the first load lock;
   a first device including a body for isolating the processing chamber from the first load lock;
   a second device for isolating the processing chamber from the second load lock;
   at least one track through the processing chamber and the first and second load locks, the track structured and arranged such that an article slides thereon under the force of gravity; and
   a plurality of passages through the body defining a plurality of inlets and outlets, a first actuator for rotating the body, a second actuator for translating the body, and a plurality of sealing portions on the body, the plurality of sealing portions corresponding to each of the passages for sealing the body with respect to openings into a chamber adjacent the body.

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