

DUAL SUBSTRATE LOADLOCK PROCESS EQUIPMENT

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1 FIELD OF THE INVENTION

2 The present invention relates to substrate processing systems, and, more
3 particularly, to loadlock systems for handling substrates.

4 BACKGROUND OF THE INVENTION

5 Substrates such as, for example, glass panels used in applications such as
6 television and computer displays may be fabricated using sequential steps including
7 physical vapor deposition (PVD), chemical vapor deposition (CVD), etching, and
8 annealing to produce the desired device. These steps may be carried out using a variety
9 of processing systems having multiple chambers. One such system is known as a
10 "cluster tool". A cluster tool generally includes a central wafer handling module or transfer
11 chamber and a number of peripheral chambers including a loadlock chamber through
12 which workpieces are introduced into and removed from the system and a plurality of
13 other chambers for carrying out processing steps such as heating, etching, and
14 deposition. The cluster tool also generally includes a robot for transferring workpieces
15 between the chambers.

16 The processing of large glass substrates used for displays is in some ways similar
17 to the processing of other types of substrates such as semiconductor wafers. Such glass
18 substrates, however, are often larger than typical silicon wafers. For example, glass
19 substrates may have dimensions of 550 mm by 650 mm, with trends towards even larger
20 sizes such as 650 mm by 830 mm and larger, to permit the formation of larger displays.
21 The use of large glass substrates introduces complexities into processing that may not be
22 present when processing other types of substrates. For example, in addition to their size,
23 glass substrates used for displays are typically rectangular in shape. The large size and
24 shape of glass substrates can make them difficult to transfer from position to position
25 within a processing system when compared with smaller, circular-shaped substrates. As
26 a result, systems for processing glass substrates generally require larger chambers,
27 apertures, and transfer mechanisms. In addition, it is known to utilize large cassettes
28 holding approximately 12 substrates within the loadlock in order to supply a large number
29 of substrates to the processing chambers for batch processing operations. The need for
30 larger chamber sizes to handle large substrates, as well as the use of large substrate

1 cassettes in the loadlock, also leads to a requirement for larger and more powerful
2 vacuum pumps, power supplies, control mechanisms and the like and a corresponding
3 increase in system cost.

4 In addition, glass substrates often have different thermal properties than silicon
5 substrates. In particular, glass generally has a relatively low thermal conductivity, which
6 can make it more difficult to uniformly heat and cool the substrate. Temperature
7 gradients may occur across the glass substrate, which can lead to undesirable stresses in
8 the substrate upon cooling. The heat loss near the substrate edges tends to be greater
9 than near the center. Temperature gradients during processing can also result in the
10 components formed on the substrate surface having non-uniform electrical (and
11 structural) characteristics. As a result, to maintain adequate temperature control, heating
12 and cooling operations are often performed relatively slowly. As the system components
13 become larger in size, these steps may be slowed even more due to the longer time it
14 generally takes to heat and cool large components in a large volume chamber. These
15 slow operations tend to lower the system throughput.

16 SUMMARY OF THE PREFERRED EMBODIMENTS

17 Certain embodiments of the present invention relate to loadlock devices for use in
18 substrate processing systems that are relatively compact in size and that can achieve
19 substrate transfer, cooling and/or heating operations in an efficient manner.

20 One embodiment relates to a loadlock having a first support structure adapted to
21 support a first substrate and a cooling plate adapted to support a second substrate.

22 Another embodiment relates to a loadlock having a first support structure to
23 support one unprocessed substrate and a second support structure to support one
24 processed substrate. The first support structure is located above the second support
25 structure and an elevator is provided to control the vertical position of the support
26 structures. The loadlock also includes a first aperture to permit insertion of an
27 unprocessed substrate into the loadlock and removal of a processed substrate from the
28 loadlock, as well as a second aperture to permit removal of an unprocessed substrate
29 from the loadlock and insertion of a processed substrate into the loadlock. A cooling plate
30 having a surface adapted to support a processed substrate is also included in the
31 loadlock. The cooling plate may be designed to have multiple zones for preferentially
32 controlling the cooling rate of a processed substrate thereon. A heating device is also
33 provided in the loadlock above the first support structure. The heating device may be
34 used to heat an unprocessed substrate on the first support structure prior to inserting the

1 unprocessed substrate into another chamber for subsequent processing.

2 Another embodiment relates to a semiconductor processing system having at
3 least one processing chamber, a transfer chamber connected to the processing chamber,
4 and a loadlock connected to the transfer chamber. The loadlock includes a single
5 substrate upper support structure and a single substrate lower support structure, as well
6 as a transfer aperture to transfer a single substrate between the transfer chamber and the
7 loadlock. The loadlock also includes an elevator for raising and lowering the supports and
8 a cooling plate positioned to accept a single substrate from the single substrate lower
9 support structure.

10 Another embodiment relates to a loadlock including a loadlock chamber and a
11 support structure in the chamber. The support structure is adapted to accept a single
12 substrate from a robot arm. A cooling plate is also located in the chamber and is
13 positioned to accept a single substrate from the support structure. The support structure
14 is movable relative to the cooling plate.

15 Another embodiment relates to a loadlock system having a first means for
16 supporting only a single unprocessed substrate and a second means for supporting only a
17 single processed substrate. The first means is located above the second means. The
18 system also includes a delivery means for delivering a processed substrate to a cooling
19 plate located in the loadlock system.

20 Embodiments of the present invention also relate to methods including utilizing a
21 loadlock and methods for processing substrates. One such embodiment relates to a
22 method for using a loadlock including delivering an unprocessed substrate to an upper
23 support structure in the loadlock through an opening in the loadlock. The opening is
24 closed and the loadlock evacuated to the desired pressure level. The unprocessed
25 substrate is transferred to a chamber outside of the loadlock. A processed substrate is
26 delivered from a chamber outside of the loadlock (such as, for example, a transfer
27 chamber or other chamber in a processing system) to a lower support structure in the
28 loadlock. The processed substrate is delivered from said lower support structure to a
29 cooling plate in the loadlock, and the processed substrate is cooled.

30 Another embodiment relates to a method for processing substrates including
31 delivering an unprocessed substrate to an upper support structure in a loadlock through a
32 first opening in the loadlock. The opening is closed and the loadlock evacuated. The
33 unprocessed substrate is delivered to a chamber outside of the loadlock through a
34 second opening in the loadlock. A processed substrate is delivered from a chamber
35 outside of the loadlock to the lower support structure through the second opening in the

loadlock. The second support structure is lowered to deliver the processed substrate to a cooling plate in the loadlock.

Still another embodiment relates to a method for processing a substrate including delivering one unprocessed substrate from an unprocessed substrate supply located outside of a loadlock to a first loadlock support structure inside of the loadlock, using a first robot. The unprocessed substrate is transferred from the first loadlock support structure to a transfer chamber using a second robot. The unprocessed substrate is transferred from the transfer chamber to at least one processing chamber to process the unprocessed substrate to form a processed substrate. The processed substrate is transferred from the at least one processing chamber to the transfer chamber. The processed substrate is transferred from the transfer chamber to a second loadlock support structure using the second robot. The second loadlock support structure may be located below the first loadlock support structure. The processed substrate is transferred from the second loadlock support structure to a cooling plate in the loadlock and cooled. The processed substrate is removed from the loadlock using the first robot.

Yet another embodiment relates to another method for processing substrates including delivering a single unprocessed substrate to an upper support structure in a loadlock and evacuating the loadlock. The single unprocessed substrate is delivered from the loadlock to the transfer chamber. A single processed substrate is delivered from a transfer chamber to a lower support structure in said loadlock. The single processed substrate is delivered from said lower support structure to a cooling plate in said loadlock. The loadlock is vented and the single processed substrate is delivered to a location external to the loadlock and the transfer chamber. Another single unprocessed substrate is delivered to the loadlock.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention are described with reference to the accompanying drawings which, for illustrative purposes, are schematic and not drawn to scale.

Fig. 1 is a top schematic view of a cluster tool including a loadlock, transfer chamber, and processing chambers according to an embodiment of the present invention.

Fig. 2 is a cross-sectional view of a portion of the loadlock of Fig. 1 in accordance with an embodiment of the present invention.

Fig. 3 is a perspective view of a loadlock according to an embodiment of the present invention.

1 Fig. 4 is a perspective view of the loadlock of Fig. 3 including an outer body
2 section around an interior compartment according to an embodiment of the present
3 invention.

4 Fig. 5 is a perspective view of the loadlock of Figs. 3 and 4 including a cover
5 portion and a lower portion according to an embodiment of the present invention.

6 Fig. 6a is an exploded view of certain interior components of a loadlock according
7 to an embodiment of the present invention.

8 Fig. 6b is a perspective view of some of the loadlock components of Fig. 6 when
9 assembled together according to an embodiment of the present invention.

10 Figs. 7a-f illustrate a processing scheme in accordance with an embodiment of the
11 present invention.

12 Fig. 8 is a perspective view of a portion of a loadlock system in a load/unload
13 condition in accordance with an embodiment of the present invention.

14 Fig. 9 is a perspective view of a portion of a loadlock system in a cool down
15 condition in accordance with an embodiment of the present invention.

16 Fig. 10 is a cross-sectional view of a cooling plate with a coolant carrying channel
17 therein in accordance with an embodiment of the present invention.

18 Fig. 11 is a cross-sectional view of a cooling plate with a coolant-carrying channel
19 at a bottom portion of the cooling plate in accordance with an embodiment of the present
20 invention.

21 Fig. 12 is a cross-sectional view of a middle plate with a coolant carrying channel
22 therein in accordance with an embodiment of the present invention.

23 Fig. 13 is a cross-sectional view of a middle plate with a coolant carrying channel
24 at an upper portion of the middle plate in accordance with an embodiment of the present
25 invention.

26 Fig. 14 is a top view of a plate having a high emissivity area in accordance with an
27 embodiment of the present invention.

28 Fig. 15 is a cross-sectional view of a cooling plate and substrate support system
29 according to an embodiment of the present invention.

30 Fig. 16 is a top cross-sectional view of a cluster chamber according to an
31 embodiment of the present invention.

32 Fig. 17 is a top cross-sectional view of a cluster chamber according to an
33 embodiment of the present invention.

DETAILED DESCRIPTION

Certain preferred embodiments relate to loadlock systems and methods of operation. These loadlock systems may be used as part of a larger cluster type processing system. As illustrated in Fig. 1, one embodiment includes a cluster system having a central substrate handling module or transfer chamber 10, a number of peripheral process chambers 20, and at least one loadlock mechanism 30 for inserting substrates into the system and removing substrates from the system. The central transfer chamber 10 may include a robot 40 therein for picking up and delivering substrates between the various chambers. The term substrates includes substrates formed from a variety of materials including, but not limited to glasses, semiconductors, ceramics, metals, composites, and combinations thereof.

A preferred embodiment of the loadlock 30 is illustrated in the cross-sectional view of Fig. 2. The loadlock 30 preferably includes a dual substrate cassette 50, with an upper slot 51 for holding an unprocessed substrate and a lower slot 53 for holding a processed substrate. The upper slot 51 may preferably be located between an upper plate 54 and a middle plate 56 of the cassette 50. The lower slot 53 may preferably be formed between the middle plate 56 and a cooling plate 52, above a lower plate 76 of the cassette 50. The plates 54, 56 and 76 are assembled to form the cassette 50. The cooling plate 52 is almost entirely located within the cassette 50. However, it is preferably not connected to the cassette 50. Instead, flange portions 100, 102 of the cooling plate 52 are preferably attached to a frame member 64 that surrounds the cassette 50. This structure enables the cassette 50 to move independently of the cooling plate 52 by coupling the cassette to an elevator 58 (Fig. 3) through shaft 128. By moving the cassette 50 independently of the cooling plate 52, a substrate on supports 78, 80 within the lower slot 53 can be lowered onto and raised off of the cooling plate 52 by moving the cassette.

In certain preferred embodiments, a substrate on the cooling plate 52 may be cooled by positioning the cooling plate (with the substrate thereon) and the middle plate 56 very close to one another. By sandwiching the substrate between the cooling plate 52 and middle plate 56, the substrate can be cooled in an efficient manner. As will be discussed in more detail later, both the middle plate 56 and the cooling plate 52 may be water cooled and may have a high emissivity surface area.

Progressive views of the loadlock 30 are illustrated in Figs. 3-5. The cassette 50 may include an opening 62 for viewing the cassette interior during operation. Fig. 4 shows the loadlock 30 of Fig. 3, further including the loadlock body portion or frame member 64 surrounding the cassette 50. A window 66 may be provided for viewing the

1 interior of the cassette through opening 62, and a door 68 may be provided for accessing
2 the interior of the loadlock to insert and remove substrates. The elevator 58 may be
3 positioned below the cassette 50 and used to move the cassette 50 relative to the cooling
4 plate 52 and frame member 64. As shown in Fig. 2, the elevator 58 may include a shaft
5 128 attached to the bottom of the cassette 50 through a connection such one or more
6 connectors 130 and plate 132. The connectors 130 may be designed to be adjustable so
7 that the cassette 50 can be leveled if it becomes misaligned. Alternatively, the shaft 128
8 may be directly connected to the cassette 50.

9 Fig. 5 shows the loadlock 30 of Figs. 3 and 4, further including a top pressure
10 vessel portion or top cover 70 and a lower pressure vessel portion or bottom cover 72 to
11 define the loadlock chamber region. The top cover 70 and bottom cover 72 may be any
12 suitable structure capable of maintaining appropriate vacuum or other desired pressure
13 conditions and be capable of surviving elevated temperatures such as those encountered
14 during substrate heating. The loadlock 30 may also include a wheeled frame structure 74
15 for supporting and moving the loadlock 30.

16 Fig. 6a illustrates an exploded view of certain components in the loadlock 30
17 including components from the cassette 50, the cooling plate 52 and the frame member
18 64. Fig. 6b illustrates the cassette 50 assembled within the frame member 64. The
19 frame member 64 includes openings 96 and 98 on opposite sides, through which
20 substrates are inserted into and removed from the loadlock. Opening 96 may be on the
21 atmospheric side of the loadlock, and opening 98 may be on the transfer chamber side of
22 the loadlock.

23 The lower plate 76 of the cassette 50 preferably has a support structure including
24 the supports 78, 80 thereon for supporting a substrate 82. The cooling plate 52, (located
25 above the lower plate 76) may include apertures 84, 86 through which the supports 78, 80
26 may extend to support the substrate 82 in the lower slot 53. The middle plate 56
27 preferably has a support structure including supports 88, 90 thereon for supporting a
28 substrate 92 in the upper slot 51. Above the middle plate 56 (and the substrate 92) lies
29 the upper plate 54 and heating device 94. The heating device 94 may include, for
30 example, a resistance element or a heating lamp. Alternative embodiments may omit the
31 upper plate 54 and/or the heating device 94.

32 As illustrated in Fig. 6a, the heating device 94 may fit into a recess in the upper
33 plate 54 so that it moves with the cassette 50 and is always positioned close to the upper
34 support structure. Alternatively, the heating device 94 may be positioned above the upper
35 plate 54 as illustrated in Fig. 2 or at some other position in the loadlock. One preferred

1 use for the heating device is to preheat an unprocessed substrate prior to transferring the
2 substrate to other chambers. Preheating the substrate may free up one or more
3 processing chamber positions in the system which would otherwise be used as heating
4 chambers to heat the unprocessed substrate. By preheating the substrate in the
5 loadlock, such heating chambers may be eliminated. Embodiments may heat the
6 substrate to a desired temperature depending on the particular processing operation such
7 as, for example, a temperature in the range of approximately 100°C to 500°C or higher.
8 It may be possible to also use the loadlock for other types of heating operations, such as
9 annealing or ashing, if desired. For certain types of high temperature processing or
10 processing in which the substrate is heated in between other processing steps, separate
11 heating chambers may still be required.

12 Figs. 7a-f schematically illustrate several components of a loadlock as used during
13 one possible processing embodiment. Certain component sizes and shapes have been
14 altered relative to earlier figures for illustrative purposes. The components illustrated
15 include the lower plate 76, the cooling plate 52, and the middle plate 56. Lower supports
16 78, 80 are coupled to the lower plate and upper supports 88, 90 are coupled to the middle
17 plate 56. The lower plate 76 and middle plate 56 are coupled to one another to form
18 cassette 50 as indicated by the dashed lines. The lower supports 78, 80 extend through
19 apertures in the cooling plate 52. An atmospheric robot (not shown in Figs. 7a-f) delivers
20 into and removes substrates from the load lock through atmospheric opening 96 and door
21 68, and a transfer chamber robot (not shown in Figs. 7a-f) removes from and delivers
22 substrates into the loadlock through vacuum opening 98 and door 99. As seen in Figs.
23 7a-f, the cooling plate 52 is coupled to the frame 64 and does not move relative to the
24 openings 96, 98. The cassette 50 (which includes the lower plate 76, lower supports 78,
25 80, the middle plate 56, and the upper supports 88, 90), is moveable relative to the
26 openings 96, 98.

27 A condition when there are no substrates in the loadlock is illustrated in Fig. 7a.
28 This may be the condition at the beginning of a processing cycle. In one embodiment, a
29 processing method includes supplying an unprocessed substrate 92 to the loadlock. As
30 shown in Fig. 7b, upper supports 88, 90 are aligned with the opening 96 and an
31 unprocessed substrate 92 has been inserted into the loadlock through an atmospheric
32 opening from the direction indicated by the arrow. Next, the atmospheric opening door 68
33 is closed, the loadlock is evacuated and the cassette 50 is raised to place the lower
34 supports 78, 80 through openings 59 in the cooling plate 52 and into alignment with the
35 vacuum opening 98 as shown in Fig. 7c. Vacuum opening door 99 is opened so that a

1 processed substrate 82 can be delivered from a transfer (or other processing) chamber
2 (not shown) to the loadlock from the direction shown by the arrow, and placed on
3 supports 78, 80.

4 The cassette 50 may then be lowered to place the processed substrate 82 onto
5 the cooling plate 52 for cooling, as shown in Fig. 7d. Preferred embodiments may include
6 structures such as pins 57 extending from the cooling plate 52 into openings 61 in the
7 bottom of the middle plate 56. The pins 57 may act to ensure proper alignment of the
8 cooling plate 52 and middle plate 56 as well as providing a barrier to prevent a substrate
9 from sliding off of the cooling plate in a lateral direction, which may occur due to a gas
10 pressure introduced in the chamber during a cooling procedure. As can be seen in Fig.
11 7d, the cooling plate 52 and middle plate 56 may be positioned so that the processed
12 substrate 82 is essentially sandwiched between the plates. This promotes the efficient
13 cooling of the processed substrate 82. In general, the closer the middle plate 56 is
14 positioned to the processed substrate 82, the faster the cooling rate of the processed
15 substrate 82. In one example, a 5 mm gap between the middle plate 56 and the
16 processed substrate 82 provided a cooling rate that was about 5 times faster than a 1
17 inch (~25 mm) gap.

18 Fig. 7d also shows that the unprocessed substrate 92 has also been placed into
19 alignment for delivery through the vacuum opening 98 in the direction indicated by the
20 arrow. The unprocessed substrate is delivered through the vacuum opening and then the
21 vacuum door 99 is closed and the chamber vented so that another unprocessed substrate
22 92' may be placed onto the upper support 88, 90 through the atmospheric opening, from
23 the direction indicated by the arrow, as illustrated in Fig. 7e. The venting may also be
24 controlled to promote uniform cooling of the processed substrate 82. The cassette 50
25 may then be raised to lift the processed substrate off of the cooling plate 52 and into
26 position to be removed from the loadlock through the atmospheric opening 96 in the
27 direction indicated by the arrow, as shown in Fig. 7f.

28 It should be appreciated that the above steps may be varied as desired and that
29 there are numerous different processing schemes that may be performed according to
30 embodiments of the present invention. For example, another processing embodiment
31 may include heating the unprocessed substrate 92 in the loadlock prior to transferring it to
32 the transfer chamber. In such an embodiment the heating step is carried out and the
33 heated, unprocessed substrate 92 is preferably delivered through the vacuum opening 98
34 to the transfer chamber prior to delivering the processed substrate 82 from the transfer
35 chamber to the loadlock.

1 More detailed views of the cassette 50 and the cooling plate 52 are illustrated in
2 Figs. 8 and 9. The upper plate 54, middle plate 56, and lower plate 76 may be coupled
3 together through side portions 77, 79. The side portions 77, 79 may be separate pieces
4 coupled together using pins 89. Alternatively, the side portions 77, 79 may be a single
5 unit and may be integrated into one or more of the plates 54, 56 and 76.

6 As seen in Fig. 8, the lower supports 78, 80 are supporting processed substrate
7 82 above the surface of the cooling plate 52. This configuration may correspond to a
8 load/unload condition where a processed substrate 82 is being loaded into or removed
9 from the loadlock. In this embodiment the processed substrate 82 is transparent. The
10 supports 78, 80 may have a variety of structures that can support a substrate including,
11 but not limited to a pin, bolt, screw or peg-like shape. The tips of the supports may also
12 have variety of structures. For example, as illustrated in Figs. 7a, the tip of the supports
13 78, 80, 88, 90 are rounded, whereas in Fig. 9, the tips of the supports 78, 80 are flat and
14 include openings 81. As illustrated in Figs. 8 and 9, one embodiment preferably includes
15 four outer pins 78 and two central pins 80.

16 Fig 9 illustrates the position of the lower supports 78, 80 after the supports have
17 been lowered to place the processed substrate 82 on the surface of the cooling plate 52.
18 The cooling plate 52 may be designed to have one or more zones for preferentially
19 controlling the temperature of a substrate thereon. This may be accomplished by
20 providing a pattern of one or more channels or grooves 104 on its upper surface. The
21 location and number of grooves 104 is designed to control the contact area between a
22 substrate and the surface of the cooling plate 52 to permit better temperature control
23 during cooling. For example, if more grooves 104 per unit area are located near the
24 periphery of the cooling plate 52 than near the center, an increased surface area of the
25 substrate will contact the cooling plate 52 near its center. If the center is a heat
26 transmissive material such as, for example, a metal, then more heat will be transmitted
27 from the center of the substrate. The grooves 104 are designed to counter the thermal
28 losses, which typically occur more quickly near the periphery of the substrate. This leads
29 to a more uniform temperature distribution across the substrate during cooling. In one
30 embodiment the grooves 104 may have a width of about 6 mm and a depth of about 1
31 mm. Other dimensions may be suitable for particular applications.

32 Embodiments may also include a one or more coolant carrying channels
33 incorporated into or attached to portions of a cooling plate and a middle plate in order to
34 remove heat from the plate quickly. The coolant carrying channels may be distributed
35 along the cooling plate as desired to yield different cooling characteristics for different

portions of the cooling plate, in order to provide a more uniform temperature distribution across a substrate. Fig. 10 illustrates a cross-sectional view of an embodiment of a cooling plate 106 including a number of grooves 104 and a coolant carrying channel 108 formed therein. Fig. 11 illustrates an embodiment of a cooling plate 110 including grooves 104 and a pipe or tube 112 as a coolant carrying channel connected (permanently or detachably) to the bottom of the cooling plate 110. In certain embodiments, the middle plate acts like a second cooling plate to assist in cooling a processed substrate. Fig. 12 illustrates an embodiment of a middle plate 116 including a coolant carrying channel 118 therein. Fig. 13 illustrates an embodiment of a middle plate 120 having a pipe or tube 122 as a cooling carrying channel connected (permanently or detachably) to the top of the middle plate 120.

Embodiments may also include a cooling plate and a middle plate each including a surface having multiple characteristics such as a different surface finish in different locations. For example, a dull and/or black finish (or other dark color finish) may accelerate cooling due to greater heat absorption than a reflective and/or smooth finish, which will reflect more heat back to the substrate. Anodizing or bead blasting all or part of the cooling plate can form a preferred high emissivity finish that may accelerate cooling. As illustrated in Fig. 14, for example, the surface of a plate 130 (such as a cooling plate and/or a middle plate) may contain a high emissivity central area 131. As seen in fig. 14, the high emissivity central area 131 of the plate 130 is viewed through a transparent substrate 132. The substrate 132 preferably has a larger size than the high emissivity area 131 (and a smaller size than the plate 130). In certain embodiments, in order to more uniformly cool the substrate it is desirable to not provide the high emissivity region 130 near the edges of the substrate 132. This is because the edges of the substrate 132 tend to cool more quickly than its center area, so providing the high emissivity region 130 over the entire surface would lead to the edges of the substrate 132 cooling much faster than the central area. Such non-uniform cooling can cause undesirable stresses and/or warping of the substrate 132.

The top and bottom covers 70, 72 (Fig. 2) of the loadlock 30 may include flanges 116 and o-rings 118, which are used to mount the top cover 70 and lower cover 72 to the loadlock frame member 64. Top cover 70 may also include inlet/outlet vent 120, which may include a gas delivery pipe or tube through which a gas may be delivered to the interior of the loadlock. A variety of gases may be delivered to the loadlock depending on the processing operation (cooling, annealing, preheating, ashing, etc.) to be carried out. In certain embodiments, it is preferred that a cooling gas is delivered into the chamber

1 upon venting to assist in cooling a processed substrate on the cooling plate 52. Preferred
2 cooling gases for use in the chamber include nitrogen and/or helium. Other inert gases
3 including, but not limited to argon and neon could also be used. Certain embodiments
4 utilize a mixture of helium and nitrogen at pressures of about 754-759 torr nitrogen and
5 about 1-6 torr helium. In one preferred embodiment, cooling gas is supplied to the
6 chamber by venting the chamber at 3 torr helium and 757 torr nitrogen. This cooling
7 scheme has been observed to provide a uniform and rapid cooling. Preferred
8 embodiments may also include helium alone as the cooling gas due to its inert nature and
9 thermal conductivity. It is preferred that the substrate be cooled with a uniformity of about
10 100°C or less along the substrate, even more preferably about 50°C or less. If desired a
11 filter 122 (Fig. 2) may be positioned near the top of the loadlock to filter out undesirable
12 particles and to promote uniform distribution of gas throughout the loadlock chamber.
13 The filter 122 may be held in place by holder 124 and may be adjusted using screw 126.

14 In certain preferred embodiments, the lower supports 78, 80 extend through
15 apertures in the cooling plate 52. Alternative embodiments may utilize a lower support
16 extending adjacent to the cooling plate instead of through the apertures in the cooling
17 plate. As illustrated in Fig. 15, one such embodiment may include a support 136 adjacent
18 to a cooling plate 138 including one or more movable arms 140 which may be lowered
19 into one or more grooves 142 in the cooling plate 138 in order to deposit a processed
20 substrate 82 on the upper surface of the cooling plate 138.

21 Other embodiments may include a loadlock having components similar in some
22 ways to those illustrated in 6a, but including a single opening for transferring substrates in
23 and out of the loadlock and between the loadlock and a transfer chamber.

24 Several embodiments of cluster processing systems according to embodiments of
25 the present invention are illustrated in Figs. 16 and 17. Fig. 16 illustrates a system 158
26 which, according to one embodiment, includes a supply of unprocessed substrates from
27 an unprocessed substrate cassette 162, which may be supplied to the loadlock 160 from
28 a substrate cassette and robot station 164 one at a time using a robot 166. The loadlock
29 160 may have a similar structure to the loadlock 30 shown in Figs. 2-4. Once an
30 unprocessed substrate is inside the loadlock 160, the loadlock 160 is evacuated and the
31 unprocessed substrate is transported to the transfer chamber 168 having a second robot
32 170 therein. Once inside the transfer chamber 168, the unprocessed substrate is
33 transferred between chambers for processing. In one embodiment, the substrate is first
34 transported to chamber 172 for heating, then back to the transfer chamber 168, and then
35 to another processing chamber 174, which may be any other type of processing chamber

1 such as, for example, a chemical vapor deposition (CVD) chamber, a physical vapor
2 deposition (PVD) chamber, or an etching chamber. After treatment in a processing
3 chamber 174, the substrate may be transported to the transfer chamber 168 and then to
4 another processing chamber 174. When the substrate is fully processed as desired, it is
5 then delivered from the final processing chamber to the transfer chamber 168 and back to
6 the loadlock 160. The processed substrate may then be cooled in the loadlock 160.
7 Cooling may take place while the loadlock 160 is evacuated and may also take place as
8 the loadlock 160 is vented. Once venting is complete and the processed substrate is
9 sufficiently cooled (such as, for example, to about 100°C), the processed substrate may
10 be removed from the loadlock 160 using the robot 166 and delivered to a processed
11 substrate cassette 176 at the station 164.

12 Another embodiment of a processing system 178 in some ways similar to that of
13 Fig. 16 is illustrated in Fig. 17. However, the embodiment of Fig. 17 includes two
14 loadlocks 160 and five processing chambers 174, as well as one heating chamber 172
15 and transfer chamber 168 having a robot 170 therein. This embodiment may be
16 particularly useful when the processing can be carried out quickly and throughput can be
17 increased by supplying more substrates to the system. As illustrated, the system 178
18 includes a larger station 165 having more cassettes 162, 176 for supplying unprocessed
19 substrates to the loadlocks 160 and for accepting processed substrates from the
20 loadlocks 160 using the robot 167. Certain embodiments of the present invention may
21 include a heater within the loadlock. When using such embodiments, it may be possible
22 to eliminate the heating chamber such as heating chamber 172 of Figs. 16 and 17. In
23 such a case an additional processing chamber 174 may be used if desired, and if only
24 one loadlock 160 is used, the system will have seven processing chambers. Depending
25 on the desired processing steps and the platform used, any number of processing
26 chambers, loadlocks, and heating chambers may be used. Certain platforms may also
27 utilize more than one transfer chamber.

28 Selected embodiments of the present invention can provide one or more of a
29 number of advantages. For example, in certain embodiments, a single loadlock chamber
30 can be used for both cooling processed substrates and heating unprocessed substrates.
31 Various features also enable a large glass substrate to be cooled or heated quickly,
32 thereby increasing the throughput of the system. Various aspects of the loadlock design
33 may help to control the temperature of a substrate on the cooling plate to provide a more
34 uniform temperature across the substrate or to provide a particular temperature
35 distribution across the substrate. For example, the heating device 94 may in certain

embodiments be used during a cooling operation in order to control the temperature distribution across a substrate. By controlling the insulative properties of the middle plate 56 and/or other portions of the loadlock, heat from the heating device 94 may be transmitted to a portion of a substrate in order to control its temperature. In one embodiment, by keeping the outer edges of the substrate at a higher temperature than the middle regions of the substrate, the outer edges can be placed into compression as the substrate cools, thus minimizing the risk of edge failures. Cooling the outer edges of a substrate at a slower rate than the interior portions of the substrate may be accomplished in certain embodiments by directed an amount of heat from the heating element 94 around the edges of the middle plate 56 to contact the outer edge regions of the processed substrate on the cooling plate 52.

In addition, the time spent waiting during processed substrate cooling and unloading from the loadlock can be significantly shorter when using a dual substrate cassette according to embodiments of the present invention, as compared to using a loadlock having a larger cassette holding, for example, 12 substrates. In a system having a cassette holding 12 substrates in the loadlock, it may take approximately 2 minutes for the system to vent and another 8 minutes to unload the substrates from the loadlock after it has been vented when using a robot arm to unload each substrate. Certain embodiments of the present invention (which have a considerably smaller interior chamber volume than a loadlock having a 12 substrate cassette therein) may preferably accomplish both the venting and removal of a processed substrate in a time of up to about a minute, or more preferably about 30 seconds. In addition, certain embodiments which have a heating element in the loadlock can heat a substrate quickly due to the relatively small interior volume in the loadlock and because the substrate can be located close to the heater. Preferred embodiments can heat the substrate in a time of less than one minute, or more preferably about 30 seconds.

The faster venting, substrate removal, and/or heating time provided by selected embodiments of the present invention offer several advantages. First, the throughput of the system may, for certain types of processing, be higher. Certain embodiments can permit a fast tact time, which is the time it takes one substrate to enter the system, be processed, and then exit the system. Second, the need to use a robot having the greatest speed possible (for unloading the substrates) may be reduced because the system can have less down time. Using a slower speed robot may improve the reliability of the processing system.

Depending on the processing steps to be carried out, it may in certain

embodiments be desirable to have 0 or 1 substrate in the loadlock at any one time. In other embodiments, it may be desirable to have up to 2 substrates in the loadlock at any one time. Alternative embodiments may permit more than 2 substrates to be located in the loadlock at any one time. Selected embodiments of the present invention may achieve a high throughput despite having fewer substrates in the system at any one time than in certain other systems. For example, one batch processing system having a substrate cassette in the loadlock may at certain times have approximately 40 substrates in the system, with 12 substrates in the loadlock, 12 substrates in a heating chamber, and 16 substrates being processed in the other system chambers. Matching the number of substrates in the loadlock and heating chamber can permit smooth substrate transferring due to a symmetrical layout of the system. A system according to certain preferred embodiments of the present invention may at certain times have approximately 15 substrates in the system, with 1 in the loadlock, 8 in a heating chamber, and 6 substrates in the other system chambers. These numbers may vary considerably depending on the configuration of the various chambers in the system. Depending on the exact processing steps and their duration, due to the faster insertion and removal of substrates, certain embodiments of the present invention may have a higher overall throughput per time period than a system that having a 12-substrate cassette in the loadlock.

The smaller size of the loadlock dual substrate cassette of certain embodiments of the present invention relative to the loadlock cassettes used in some other systems also enables to loadlock to be fabricated from less material and to utilize smaller vacuum, elevator, power components and the like. These smaller components can make the system considerably less expensive than larger systems including multiple substrate cassettes within the loadlock.

Typical processing pressures used in the various chambers described above may range from about 10^{-8} torr to several torr and vary depending on the chamber and the process steps (PVD, CVD, etching, annealing, etc) being performed. It is generally desired that the pressure difference between adjacent chambers be kept to a minimum or controlled when adjacent chambers are in communication with each other in order to minimize contamination.

Embodiments of the present invention also include other types of processing systems such as linear systems in which a substrate may be transported from a loadlock to one or more processing chambers sequentially and then to the same or another loadlock, depending on the system layout.

It will, of course, be understood that modifications of the present invention, in its

1 various aspects, will be apparent to those skilled in the art. A variety of additional
2 embodiments are also possible, their specific designs depending upon the particular
3 application. As such, the scope of the invention should not be limited by the particular
4 embodiments herein described but should be defined by the claims.

WHAT IS CLAIMED IS:

1 1. A loadlock comprising:
2 a chamber body;
3 a first support structure in said chamber body adapted to support a substrate in
4 direct contact therewith;
5 a second support structure in said chamber body adapted to support a
6 substrate in direct contact therewith;
7 said first support structure being disposed above said second support structure;
8 an elevator to control a position of said first support structure and said second
9 support structure so that said first support structure and said second support structure
10 move in unison;
11 a cooling plate including a surface adapted to support a processed substrate
12 thereon; and
13 a heating device located above said first support;
14 wherein said second support structure extends through said cooling plate when
15 said second support structure is positioned to support a substrate.

1 2. A loadlock as in claim 1, further comprising a first aperture adapted to
2 permit insertion of an unprocessed substrate into said loadlock and removal of a
3 processed substrate from said loadlock; and a second aperture adapted to permit
4 removal of an unprocessed substrate from said loadlock and insertion of a processed
5 substrate into said loadlock;

1 3. A loadlock as in claim 2, wherein said first support structure and said
2 second support structure are movable relative to said cooling plate.

1 4. A loadlock as in claim 3, wherein said cooling plate is attached to said
2 chamber body.

1 5. A loadlock as in claim 1, wherein said cooling plate has a plurality of
2 openings extending from a bottom surface of said cooling plate to a top surface of said
3 cooling plate to permit said second support structure to extend therethrough.

1 6. A loadlock as in claim 3, further comprising a middle plate between said
2 first support structure and said second support structure.

1 7. A loadlock as in claim 6, wherein said cooling plate includes at least one
2 alignment structure extending therefrom and said middle plate includes at least one
3 opening sized to accommodate said at least one alignment structure extending from
4 said cooling plate.

1 8. A loadlock as in claim 7, wherein said first support structure is
2 connected to said middle plate.

1 9. A loadlock as in claim 6, wherein said middle plate includes a cooling
2 layer and an insulation layer.

 10. A loadlock as in claim 1, wherein said first support structure comprises a
plurality of pins and said second support structure comprises a plurality of pins.

1 11. A loadlock as in claim 1,
2 wherein said first support structure includes outer supports and inner supports,
3 wherein when a substrate is positioned on said first support structure, said outer
4 supports are adapted to contact an outer portion of the substrate and said inner
5 supports are adapted to contact an inner portion of said substrate; and
6 wherein said second support structure includes outer supports and inner
7 supports, wherein when a substrate is positioned on said second support structure,
8 said outer supports are adapted to contact an outer portion of the substrate and said
9 inner supports are adapted to contact an inner portion of said substrate

1 12. A loadlock as in claim 1, wherein said elevator is positioned below said
2 cooling plate.

1 13. A loadlock as in claim 1, wherein said cooling plate includes a plurality
2 of openings sized so that said second support structure may extend therethrough
3 without contacting said cooling plate.

1 14. A loadlock as in claim 1, wherein said first and second support
2 structures are sized to accept a glass substrate having a rectangular shape including a
3 length of at least 650 mm and a width of at least 830 mm.

1 15. A loadlock as in claim 1, further comprising a gas inlet adapted to supply
2 a gas to said loadlock, said gas inlet positioned along a top surface of said loadlock.

1 16. A loadlock comprising:
2 a chamber body;
3 a first support structure in said chamber body adapted to support one
4 unprocessed substrate;
5 a second support structure in said chamber body adapted to support one
6 processed substrate;
7 said first support structure being disposed above said second support structure;
8 an elevator to control a vertical position of said first support structure and said
9 second support structure;
10 a first aperture to permit insertion of an unprocessed substrate into said
11 loadlock and removal of a processed substrate from said loadlock;
12 a second aperture to permit removal of an unprocessed substrate from said
13 loadlock and insertion of a processed substrate into said loadlock;
14 a cooling plate including a surface adapted to support a processed substrate
15 thereon, said cooling plate being positioned below said second support structure when
16 said second support structure is supporting a processed substrate; and
17 a heating device located above said first support; and

18 a middle plate between said first support structure and said second support
19 structure.

1 17. A loadlock as in claim 16, wherein said cooling plate includes at least
2 one structure extending therefrom and said middle plate includes at least one opening
3 sized to accommodate said at least one structure extending from said cooling plate.

1 18. A loadlock as in claim 16, wherein said first support structure is
2 connected to said middle plate.

1 19. A loadlock as in claim 16, wherein said middle plate includes a cooling
2 layer and an insulation layer.

1 20. A loadlock for processing display substrates, comprising:
2 a chamber body defining a first aperture on a first side surface and a second
3 aperture on a second side surface;
4 an upper support structure adapted to support a display substrate;
5 a middle plate connected to said upper support structure;
6 a lower support structure adapted to support a display substrate;
7 a lower plate connected to said lower support structure;
8 a single cooling plate positioned in said chamber, said single cooling plate
9 being positioned between said middle plate and said lower plate;
10 a heating element disposed above said upper support structure;
11 an upper plate positioned above said upper support structure;
12 wherein said upper plate, middle plate, and lower plate are connected to each
13 other so that said upper plate, middle plate, and lower plate can move together in a
14 vertical direction independent of said cooling plate; and
15 wherein said heating element is positioned on or above said upper plate.

1 21. A loadlock as in claim 20, further comprising a processed display
2 substrate on said lower support and an unprocessed display substrate on said upper
3 support structure at the same time.

1 22. A loadlock as in claim 20, wherein said display substrates comprise
2 glass.

1 23. A loadlock as in claim 20, wherein said upper support and said lower
2 support structures are sized to accept a glass substrate having a rectangular shape
3 including a length of at least 650 mm and a width of at least 830 mm.

1 24. A loadlock as in claim 20, further comprising a gas inlet and a gas
2 supply, said gas supply including helium gas.

1 25. A loadlock as in claim 24, further comprising a filter disposed adjacent to
2 said gas inlet.

1 26. A loadlock as in claim 20, further comprising an elevator coupled to said
2 lower plate and adapted to move said lower plate, said middle plate and said upper
3 plate in a vertical direction, wherein said cooling plate is stationary when said lower
4 plate, said middle plate and said upper plate are moved by said elevator.

1 27. A loadlock as in claim 20, wherein said middle plate includes a cooling
2 layer and an insulation layer.

1 28. A loadlock as in claim 20, wherein said upper support and said lower
2 support structures each comprise a plurality of supports adapted to support a display
3 substrate in direct contact therewith.

1 29. A substrate processing system as in claim 20, wherein said lower
2 support structure includes inner supports and outer supports, said outer supports being
3 located closer to a periphery of said lower plate than said inner supports, and wherein
4 said cooling plate includes a plurality of openings therein sized to permit said inner
5 supports and said outer supports of said lower support structure to extend
6 therethrough.

1 30. A loadlock comprising:
2 a chamber;
3 a lower plate having a plurality of supports extending therefrom, said supports
4 adapted to support a single substrate in said chamber;
5 a cooling plate disposed in said chamber, said cooling plate positioned to
6 accept a single substrate from said support structure, said cooling plate including a
7 plurality of apertures therethrough that are sized to permit said supports extending from
8 said lower plate to extend therethrough;
9 a middle plate having a plurality of supports extending therefrom, said supports
10 extending from said middle plate adapted to accept a single substrate, said middle
11 plate positioned above said cooling plate;
12 said lower plate being spaced apart from and below said cooling plate; and
13 said lower plate and plurality of supports extending from said lower support
14 being adapted to move in a vertical direction independent of said cooling plate.

1 31. A loadlock as in claim 30, wherein said middle plate includes an
2 insulation layer thereon.

1 32. A loadlock as in claim 30, wherein said middle plate and said lower plate
2 are connected to each other and adapted to move together in a vertical direction.

1 33. A loadlock as in claim 32, further comprising an upper plate positioned
2 above said middle plate and coupled to said middle plate and said lower plate so that
3 said upper plate, middle plate and lower plate move together in a vertical direction.

1 34. A loadlock as in claim 30, further comprising a heating element
2 positioned above said middle plate.

1 35. A loadlock as in claim 30, further comprising an elevator connected to
2 said lower plate and adapted to control a vertical position of said lower plate and

3 plurality of supports while at the same time said cooling plate remains in a fixed vertical
4 position.

1 36. A loadlock as in claim 35, wherein said elevator is positioned below said
2 lower plate.

1 37. A loadlock as in claim 30, wherein said plurality of supports includes
2 outer supports and inner supports, said inner supports positioned closer to a center
3 region of the lower plate than said outer supports.

1 38. A substrate processing system comprising:
2 at least one processing chamber;
3 a transfer chamber connected to said at least one processing chamber; and
4 a loadlock connected to said transfer chamber, said loadlock comprising:
5 a chamber body;
6 a first support structure in said chamber body adapted to support
7 a substrate in direct contact therewith;
8 a second support structure in said chamber body adapted to
9 support a substrate in direct contact therewith;
10 a transfer aperture to transfer a substrate between said transfer
11 chamber and said loadlock;
12 said first support structure being disposed above said second
13 support structure;
14 an elevator to control a position of said first support structure and
15 said second support structure;
16 a cooling plate including a surface adapted to support a
17 processed substrate thereon, said cooling plate surface positioned
18 between said second support structure and said first support structure in
19 said loadlock when a processed substrate is positioned on said cooling
20 plate surface; and
21 a heating device located above said first support;

22 wherein said second support structure extends through said
23 cooling plate when said second support is positioned to support a
24 substrate.

1 39. A substrate processing system as in claim 38, wherein said at least one
2 processing chamber includes at least one chamber selected from the group consisting
3 of a physical vapor deposition chamber, a chemical vapor deposition chamber, an
4 etching chamber, and a heating chamber.

1 40. A substrate processing system as in claim 39, further comprising an
2 external substrate supply station including:
3 a first robot to deliver substrates to said loadlock and pick up substrates from
4 said loadlock;
5 at least one unprocessed substrate cassette to supply unprocessed substrates
6 to said loadlock; and
7 at least one processed substrate cassette to accept processed substrates from
8 said loadlock.

1 41. A substrate processing system as in claim 40, further comprising a
2 second robot to transfer a substrate between said loadlock and said transfer chamber.

1 42. A substrate processing system as in claim 38, further comprising a gas
2 supply coupled to said loadlock.

1 43. A substrate processing system as in claim 42, wherein said gas supply
2 comprises helium.

1 44. A substrate processing system as in claim 42, wherein said gas supply
2 comprises helium and nitrogen.

1 45. A substrate processing system as in claim 44, wherein said gas is
2 supplied to said loadlock at a nitrogen partial pressure of 754-759 torr and at a helium
3 partial pressure of 1-6 torr.

1 46. A substrate processing system as in claim 38, wherein said cooling plate
2 includes a plurality of openings extending from a bottom surface thereof to a top
3 surface thereof, said openings being sized to permit said support structures to extend
4 therethrough, said openings including outer openings and inner openings, said outer
5 openings being positioned closer to a peripheral region of said plate than said inner
6 openings.

1 47. A substrate processing system comprising:
2 at least one processing chamber;
3 a transfer chamber connected to said at least one processing chamber; and
4 a loadlock connected to said transfer chamber, said loadlock comprising:
5 a single substrate upper support structure and a single substrate
6 lower support structure;
7 an elevator to raise and lower said single substrate upper
8 support structure and said single substrate lower support structure;
9 a cooling plate disposed in said loadlock and positioned to
10 accept a single substrate from said single substrate lower support
11 structure, said cooling plate being positioned below said single substrate
12 lower support structure when said single substrate lower support structure is
13 supporting a substrate;
14 a load/unload aperture through which an unprocessed substrate
15 may be loaded into said loadlock and through which a processed
16 substrate may be unloaded from said loadlock;
17 a transfer aperture through which an unprocessed substrate may
18 be delivered from said loadlock to said transfer chamber and through
19 which a processed substrate may be delivered from said transfer
20 chamber to said loadlock;

21 a heating element disposed above said single substrate upper
22 support structure; and
23 a middle plate disposed above said cooling plate and below said
24 heating element.

1 48. A substrate processing system as in claim 47, wherein said single
2 substrate upper support structure is connected to said middle plate.

1 49. A substrate processing system as in claim 48, further comprising a gas
2 inlet to supply a gas to said loadlock.

1 50. A substrate processing system as in claim 49, wherein said loadlock
2 includes a top surface, said gas inlet being located along said top surface of said
3 loadlock.

1 51. A substrate processing system as in claim 48, wherein said single
2 substrate upper support structure includes a plurality of supports extending from said
3 middle plate, including inner supports and outer supports, said outer supports being
4 located closer to a periphery of said middle plate than said inner supports.

1 52. A substrate processing system as in claim 51, further comprising a lower
2 plate to which said single substrate lower support structure is connected, said lower
3 plate being positioned below said cooling plate, wherein said single substrate lower
4 support structure includes a plurality of supports extending from said lower plate,
5 including inner supports and outer supports, said outer supports being located closer to
6 a periphery of said lower plate than said inner supports, and wherein said cooling plate
7 includes a plurality of openings therein sized to permit said inner supports and said
8 outer supports of said lower support structure to extend therethrough.