US010344380B2

(12) United States Patent
Abedijaberi et al.

(10) Patent No.: US 10,344,380 B2
(45) Date of Patent: Jul. 9, 2019

(54) **LINER ASSEMBLIES FOR SUBSTRATE PROCESSING SYSTEMS**

(71) Applicant: **SunEdison, Inc.**, St. Peters, MO (US)

(72) Inventors: **Arash Abedijaberi**, St. Peters, MO (US); **Shawn George Thomas**, Chesterfield, MO (US)

(73) Assignee: **GlobalWafers Co., Ltd.**, Hsinchu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 477 days.

(21) Appl. No.: **14/176,263**

(22) Filed: **Feb. 10, 2014**

(65) **Prior Publication Data**

US 2014/0224174 A1 Aug. 14, 2014

Related U.S. Application Data

(60) Provisional application No. 61/763,280, filed on Feb. 11, 2013.

(51) **Int. Cl.**
C23C 16/00 (2006.01)
C23C 16/455 (2006.01)
H01L 21/00 (2006.01)

(52) **U.S. Cl.**
CPC .. ***C23C 16/45504*** (2013.01); ***C23C 16/45563*** (2013.01)

(58) **Field of Classification Search**
CPC C23C 16/45504; C23C 16/45563
USPC 156/916
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,834,059 A * 11/1998 Anderson C23C 16/455 427/248.1
5,916,369 A * 6/1999 Anderson C23C 16/455 118/715
6,238,738 B1 * 5/2001 McCurdy C03C 17/2453 427/166
6,245,149 B1 * 6/2001 de Lomenie C23C 16/4405 118/715
6,500,734 B2 * 12/2002 Anderson C23C 16/45504 438/478
8,888,087 B2 * 11/2014 Okabe .... H01L 21/02617 269/289 R
8,926,753 B2 * 1/2015 Yamada C23C 16/455 117/200

(Continued)

FOREIGN PATENT DOCUMENTS

EP 1703550 A1 9/2006
JP 2002231641 A 8/2002

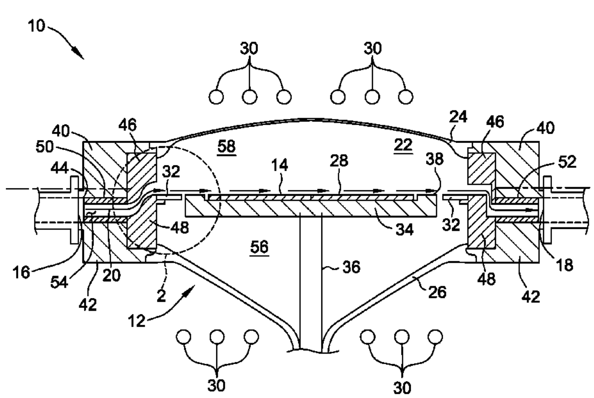
(Continued)

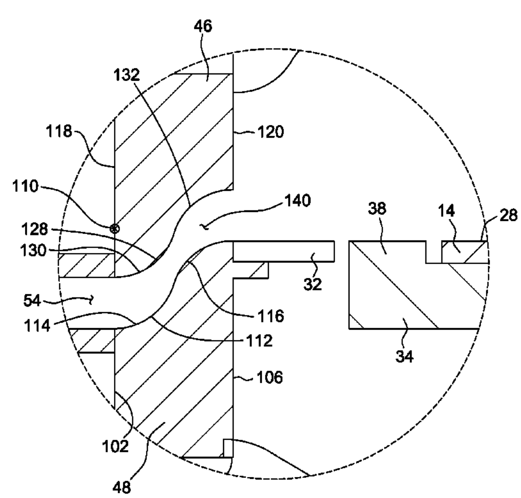
Primary Examiner — Sylvia MacArthur
Assistant Examiner — Michelle Crowell
(74) *Attorney, Agent, or Firm* — Armstrong Teasdale LLP

(57) **ABSTRACT**

A liner assembly for a substrate processing system includes a first liner and a second liner. The first liner includes an annular body and an outer peripheral surface including a first fluid guide. The first fluid guide is curved about a circumferential line extending around the first liner. The second liner includes an annular body, an outer rim, an inner rim, a second fluid guide extending between the outer rim and the inner rim, and a plurality of partition walls extending outwardly from the second fluid guide. The second fluid guide is curved about the circumferential line when the first and second liners are positioned within the processing system.

24 Claims, 10 Drawing Sheets





(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0051312 A1* 3/2007 Sneh C23C 14/566
118/719
2007/0269983 A1* 11/2007 Sneh C23C 16/4409
438/689
2007/0281084 A1* 12/2007 Hirosawa C23C 16/45565
427/248.1
2009/0110826 A1* 4/2009 Aggarwal C23C 16/4412
427/255.28
2011/0198417 A1* 8/2011 Detmar H01J 37/321
239/569
2012/0240853 A1 9/2012 Carlson et al.
2014/0273503 A1* 9/2014 Pitney C23C 16/45563
438/758

FOREIGN PATENT DOCUMENTS

JP 2003086524 A 3/2003
JP 2003142400 A * 5/2003 .... H01L 21/6715
WO 2012128783 A1 9/2012

* cited by examiner

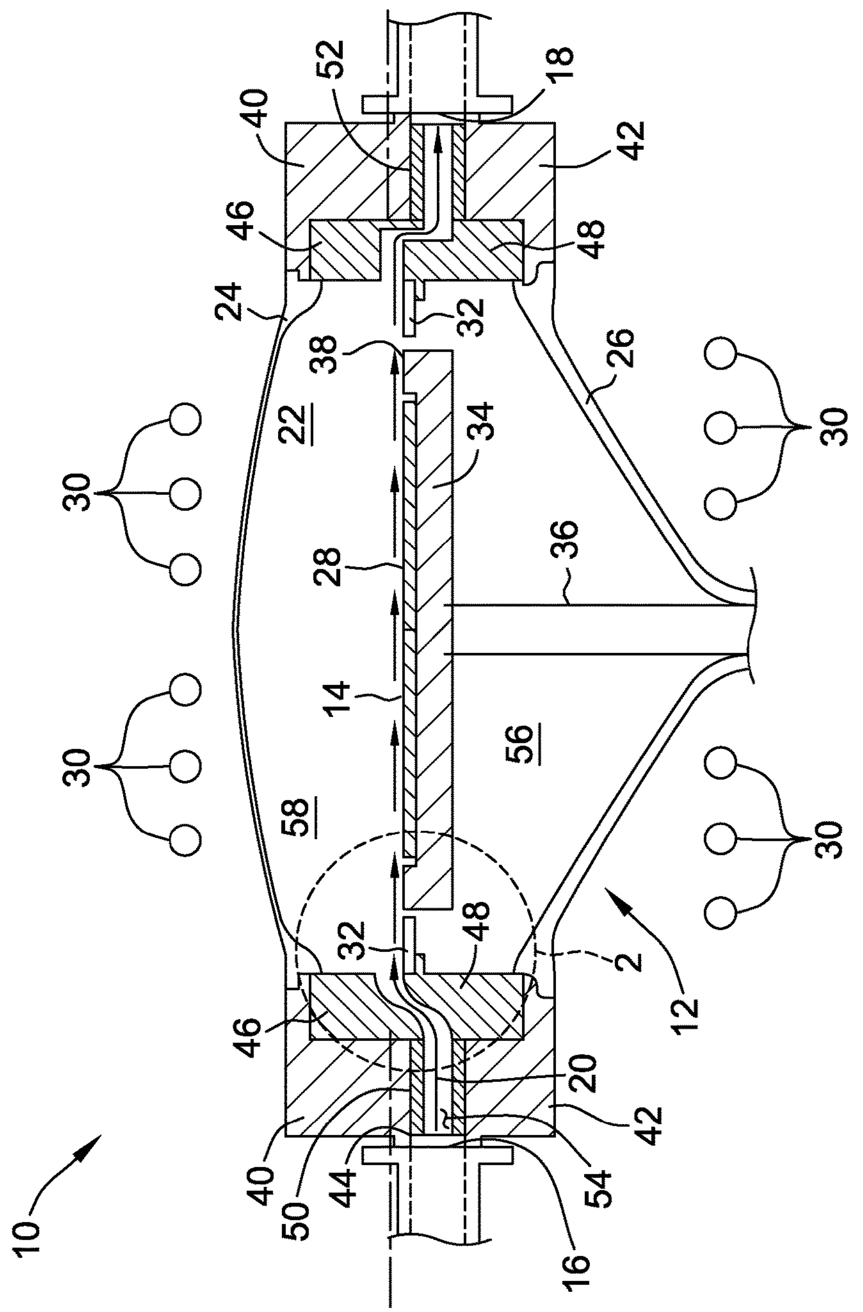

10
12
14
16
18
2
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58

FIG. 1

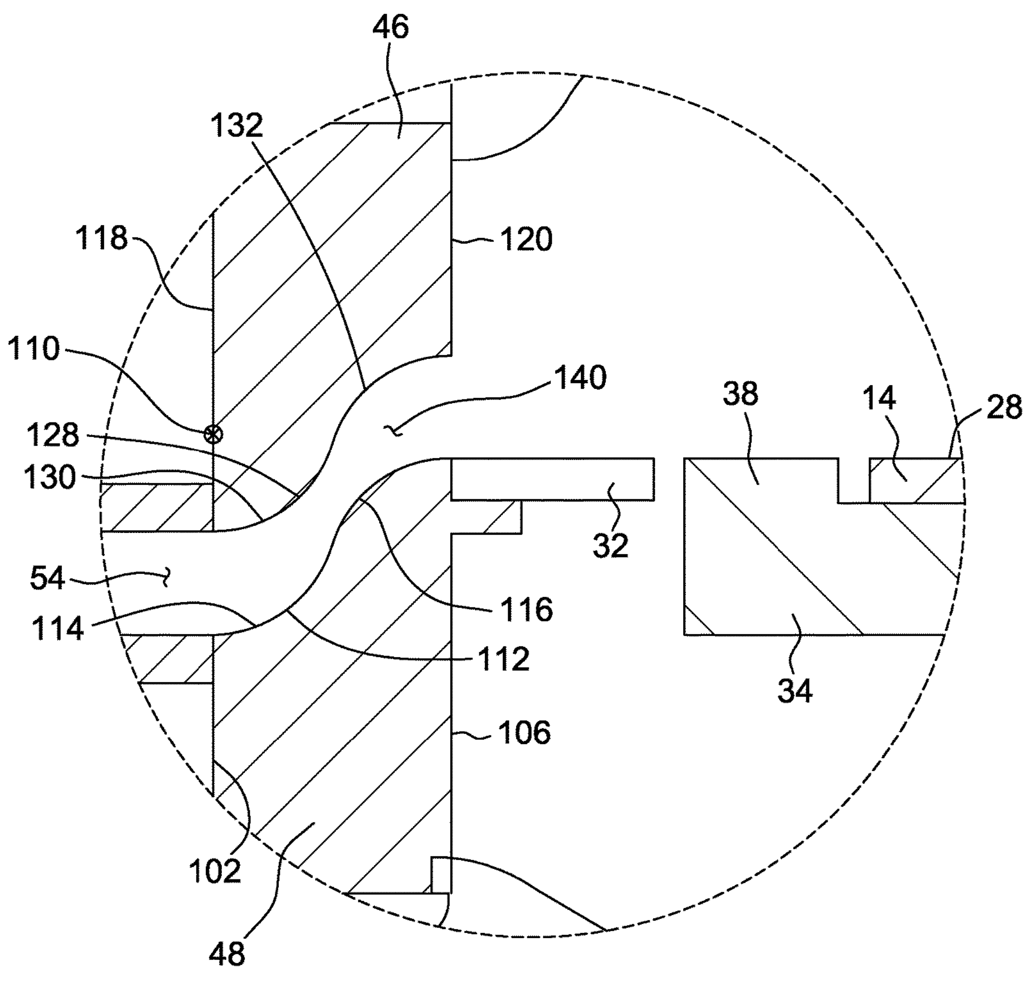

46
132
118
120
110
140
38
14
28
128
130
32
54
116
114
112
34
106
102
48

FIG. 2

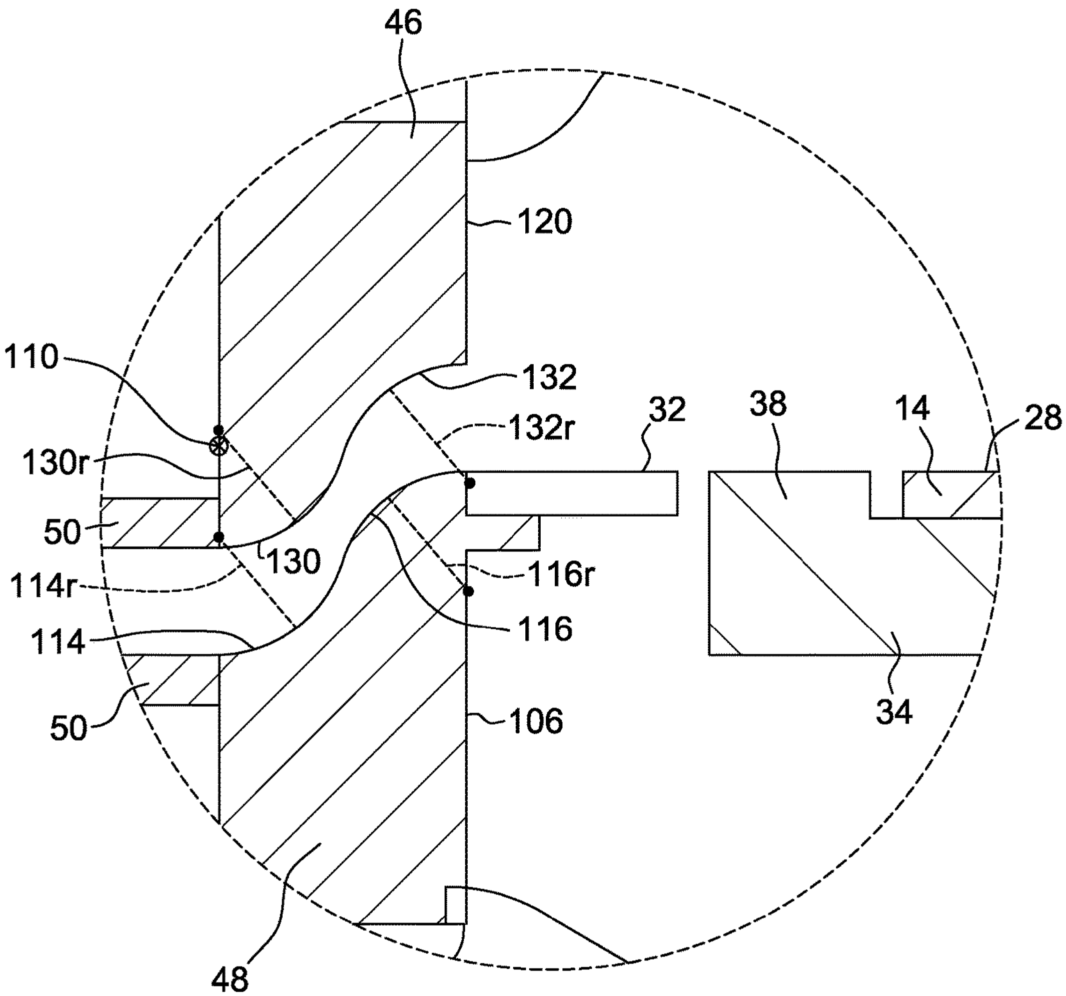

46
120
110
132
132r
32
38
14
28
130r
50
130
114r
116r
116
114
34
50
106
48

FIG. 3

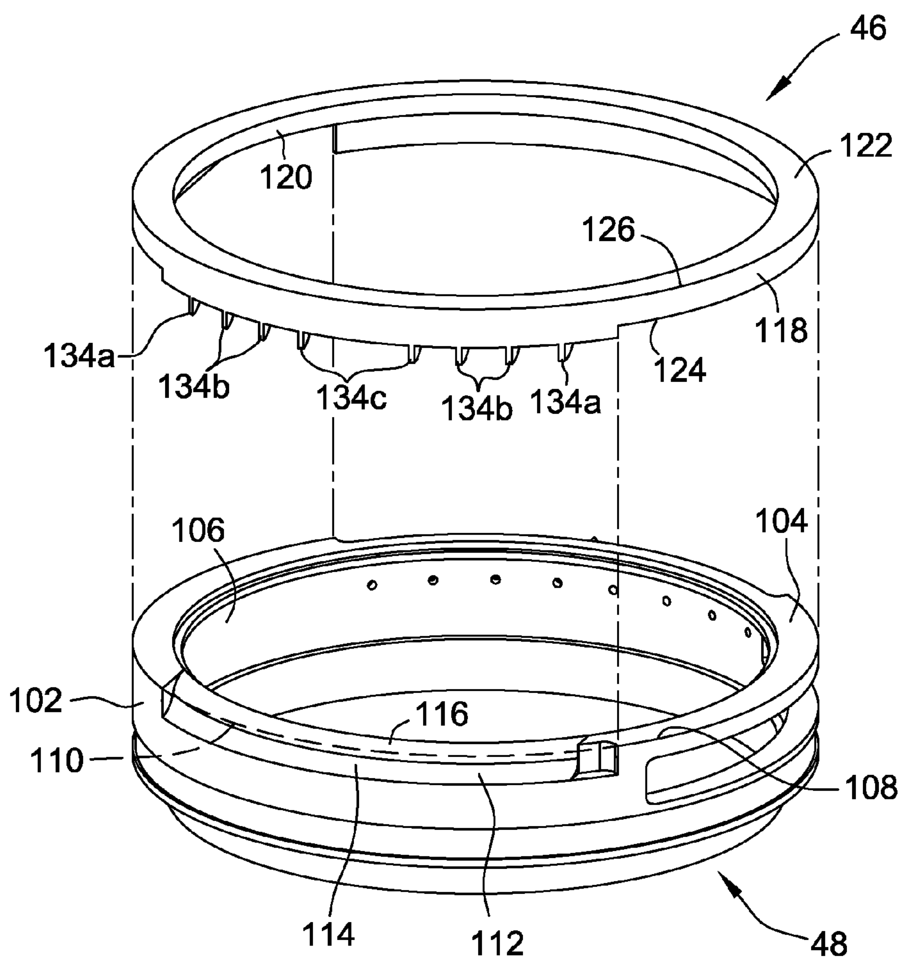

46
122
120
126
118
124
134a
134b
134c
134b
134a
106
104
102
116
110
108
114
112
48

FIG. 4

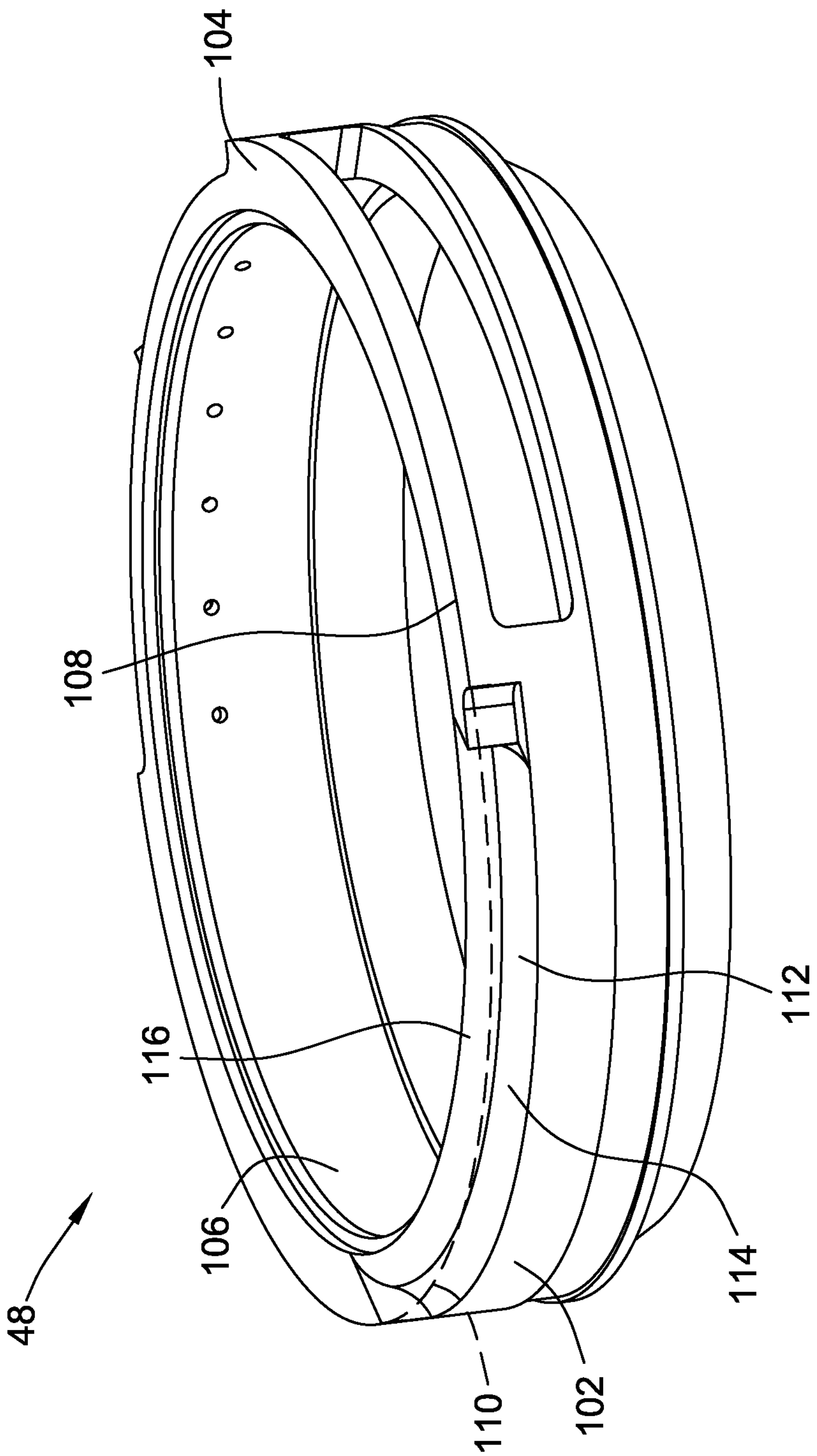


FIG. 5

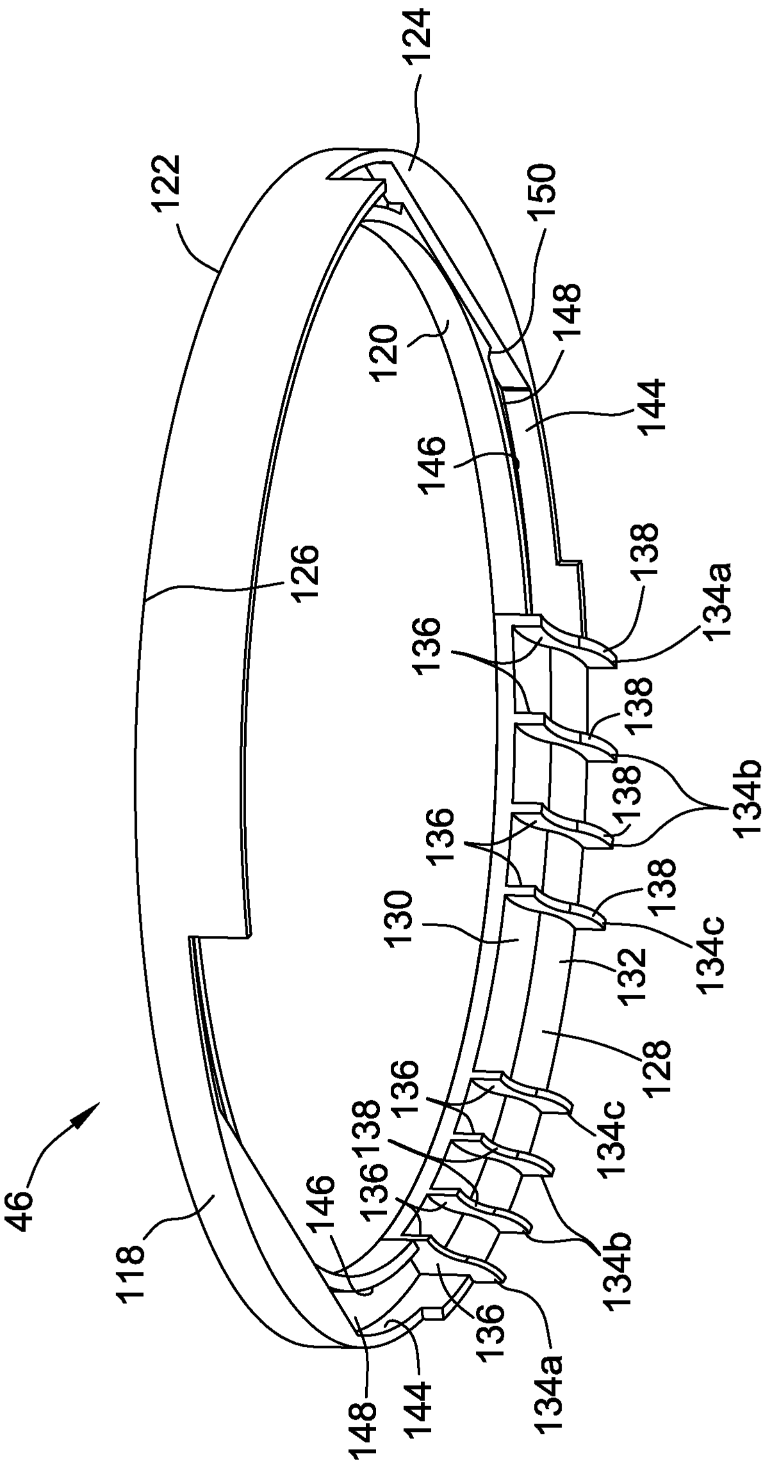

124
122
150
148
120
144
146
138
126
134a
136
138
134b
138
136
138
130
134c
132
128
136
134c
138
46
136
146
136
134b
118
136
148
144
134a

FIG. 6

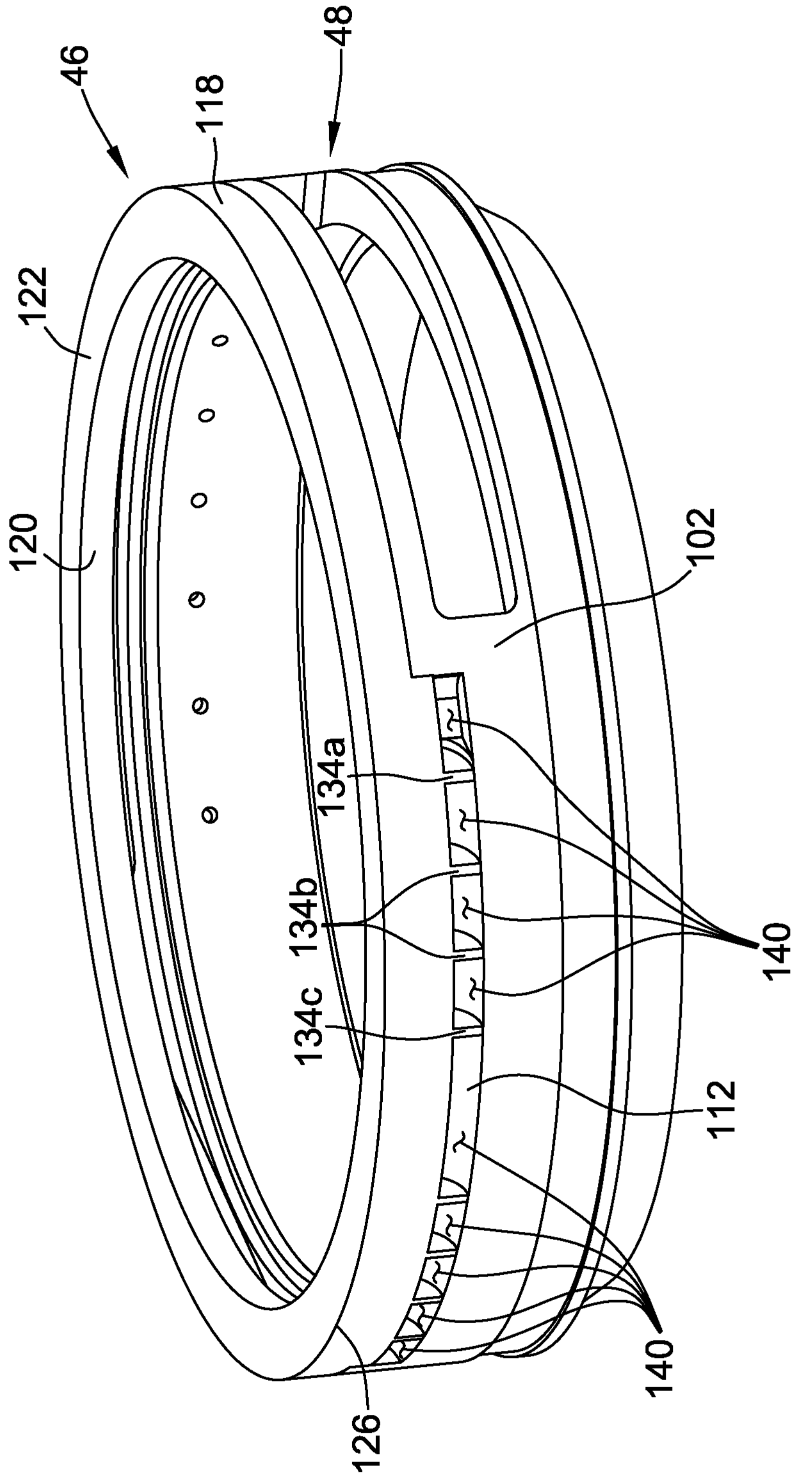


FIG. 7

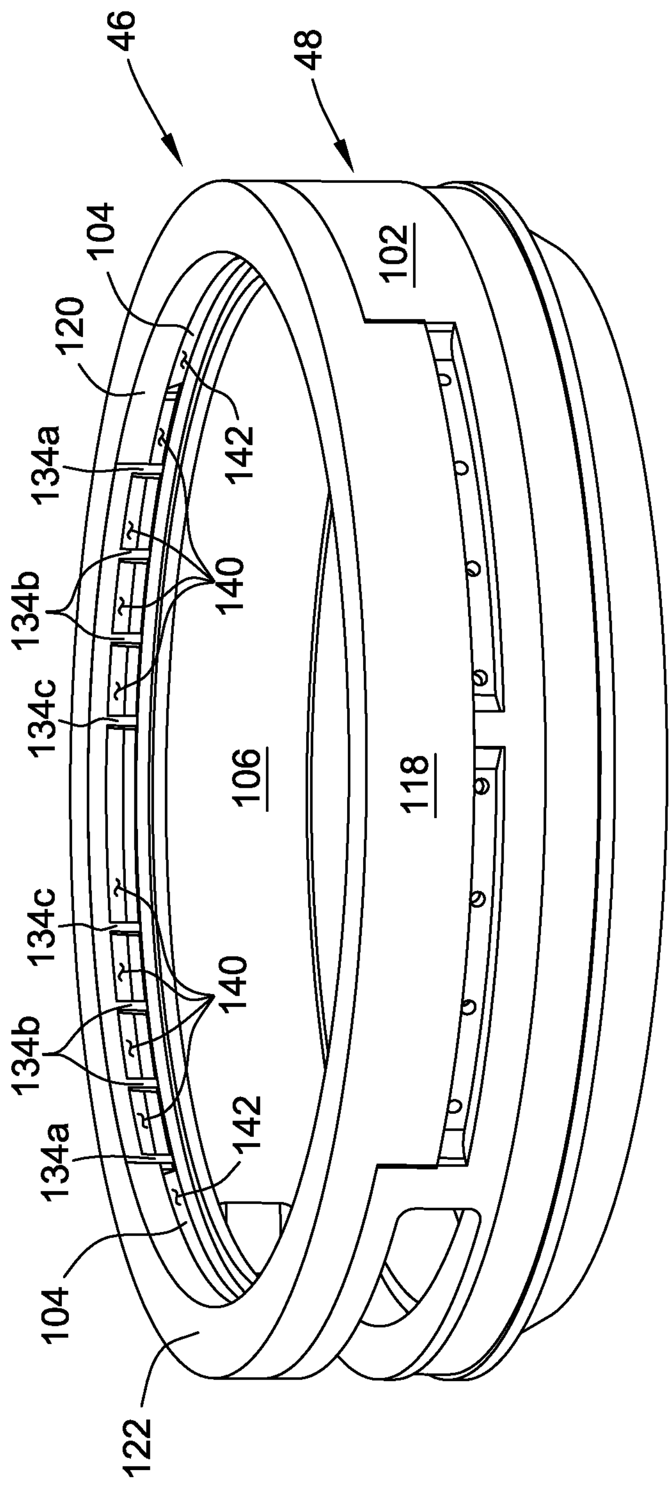

46
48
102
104
120
142
134a
140
134b
134c
106
118
134c
140
134b
142
134a
104
122

FIG. 8

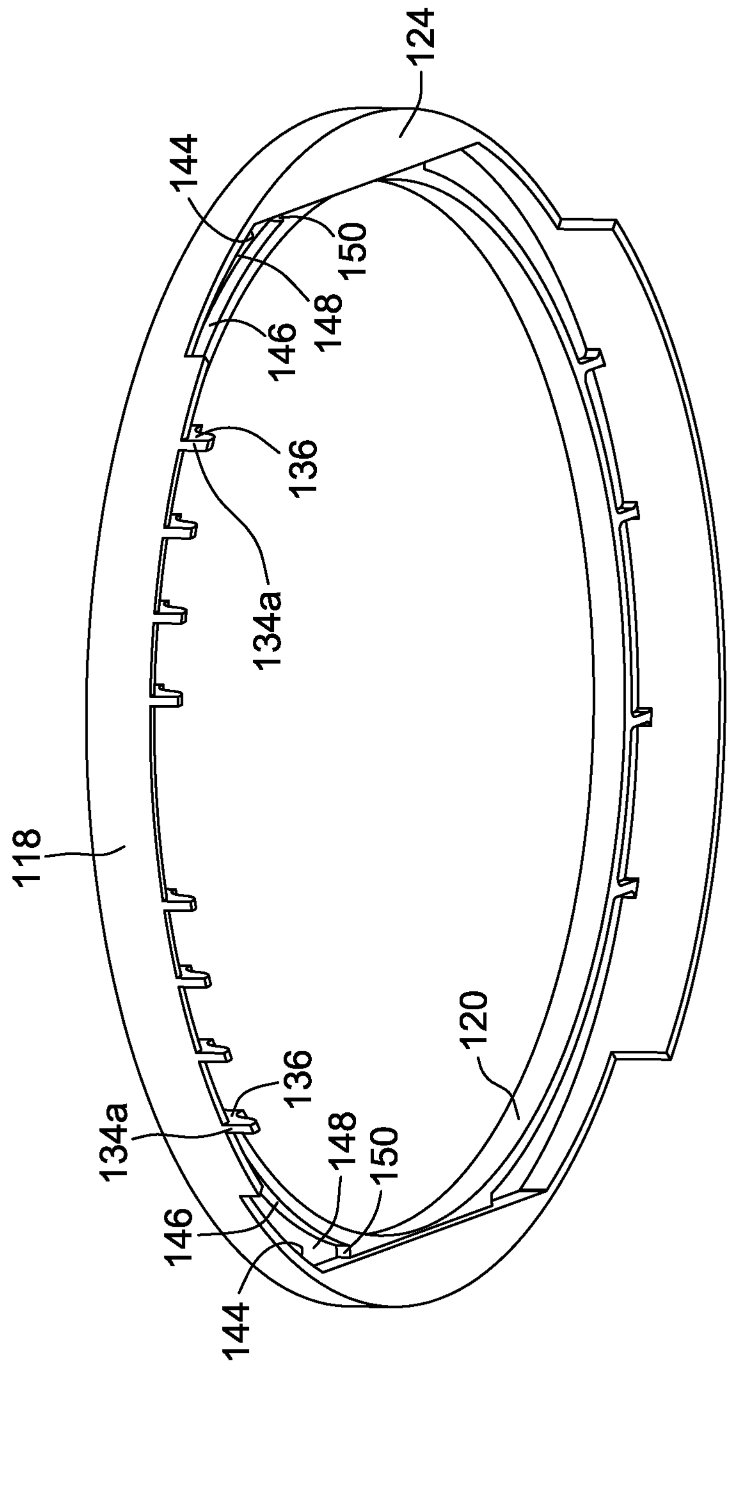


FIG. 9

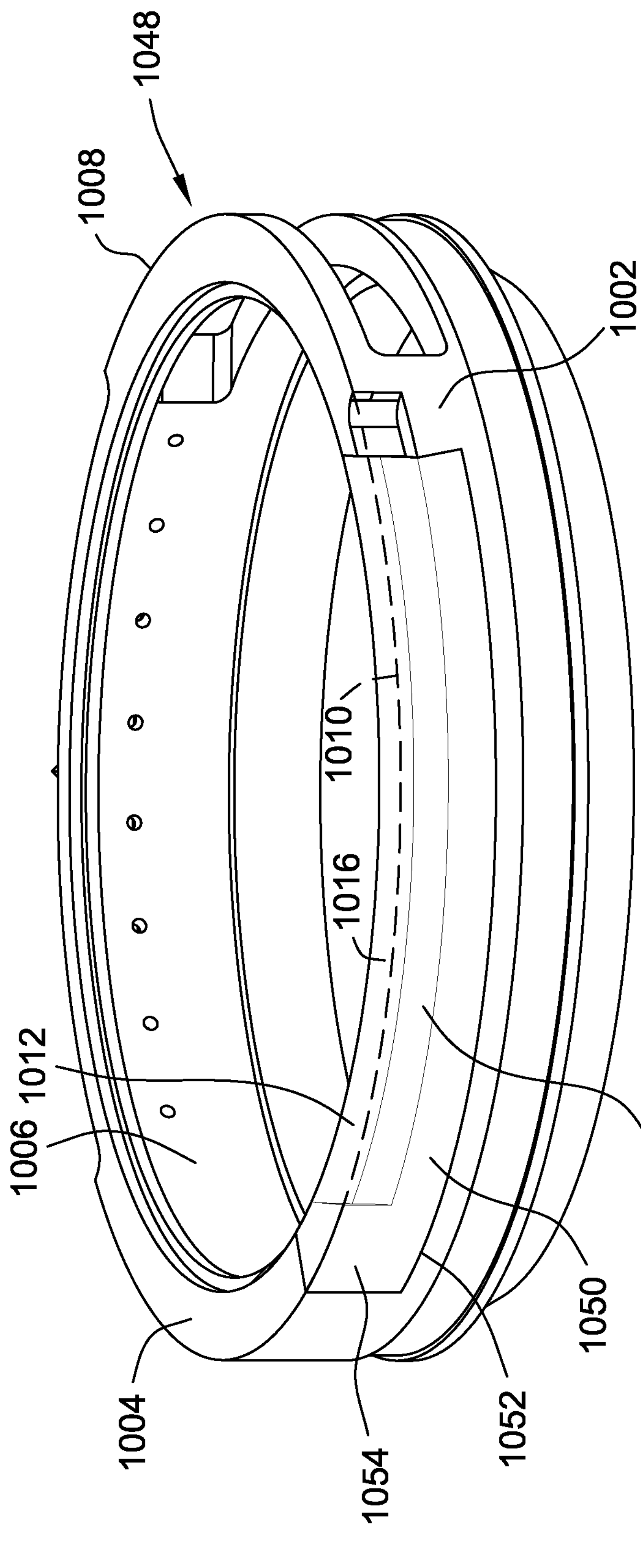


FIG. 10

LINER ASSEMBLIES FOR SUBSTRATE PROCESSING SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority to U.S. Provisional Application Ser. No. 61/763,280, filed on Feb. 11, 2013, which is hereby incorporated by reference in its entirety.

FIELD

The field relates generally to the use of chemical vapor deposition systems in processing semiconductor wafers and, more specifically, to liner assemblies for use in chemical vapor deposition chambers.

BACKGROUND

In chemical vapor deposition (CVD) processes, including epitaxial growth processes, uniformity in the thickness of a deposited film on a substrate is dependent on, among other factors, uniformity in the flow distribution of gasses within the process chamber. As the requirements for uniformity in film thickness become more stringent, the desire for more uniform flow rate distribution of gasses in the process chamber increases.

In conventional CVD devices, a source gas is introduced into the process chamber through a set of liners. Conventional liners include an upper fluid guide and a lower fluid guide that guide gas over the top surface of the substrate without disturbing its distribution to the extent possible.

However, the fluid guides of conventional liners are stepped or linearly sloped. In particular, the upper fluid guide is typically stepped and the lower fluid guide is typically stepped or linearly sloped. As a result, the fluid guides disturb the incoming gas flow such that the gas flow rate at certain regions on the substrate surface are significantly higher than others, resulting in uneven growth rates. This results in a non-uniform film thickness. These negative effects are amplified at higher flow rates, which are desirable to increase the throughput of CVD devices.

The fluid guides of conventional liners can also disturb the incoming gas flow such that little gas flows over certain regions of the substrate surface, resulting in "dead spots" on the substrate surface.

Additionally, because stepped and linearly sloped fluid guides of conventional liners disturb the incoming gas flow, the flow rate distribution across the substrate surface is highly dependent upon the incoming gas flow rate and gas type. As a result, when the gas flow rate or gas type is changed, the CVD device must be tuned by varying one or more parameters of the CVD reactor to account for changes in the flow rate distribution across the substrate surface.

A need exists for a liner assembly capable of delivering a more uniform flow rate distribution across the surface of a substrate.

This Background section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

BRIEF SUMMARY

In one aspect, a liner assembly for a substrate processing system is provided. The liner assembly includes a first liner and a second liner. The first liner includes an annular body and an outer peripheral surface including a first fluid guide. The first fluid guide is curved about a circumferential line extending around the first liner. The second liner includes an annular body, an outer rim, an inner rim, a second fluid guide extending between the outer rim and the inner rim, and a plurality of partition walls extending outwardly from the second fluid guide. The second fluid guide is curved about the circumferential line when the first and second liners are positioned within the processing system.

In another aspect, a liner assembly for a substrate processing system is provided. The liner assembly includes a first liner and a second liner. The first liner includes a first fluid guide having a concave portion and a convex portion. The second liner includes a second fluid guide having a concave portion and a convex portion. The first and second liners are configured to engage one another such that the first and second fluid guides form at least one fluid guiding channel.

In yet another aspect, a chemical vapor deposition system for processing a substrate is provided. The system includes a processing chamber, a first liner, and a second liner. The processing chamber has a processing volume enclosed therein, and includes a lower chamber wall and an upper chamber wall. The first liner is disposed between the lower chamber wall and the processing volume, and includes a first fluid guide that is curved about a circumferential line extending around the first liner. The second liner is disposed between the upper chamber wall and the processing volume, and includes an outer rim, an inner rim, and a second fluid guide extending between the outer rim and the inner rim. The second fluid guide is curved about the circumferential line.

Various refinements exist of the features noted in relation to the above-mentioned aspects. Further features may also be incorporated in the above-mentioned aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to any of the illustrated embodiments may be incorporated into any of the above-described aspects, alone or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-section of a chemical vapor deposition system including a liner assembly of one embodiment;

FIG. **2** is an enlarged view of a portion of the liner assembly of FIG. **1**;

FIG. **3** is another enlarged view of a portion of the liner assembly of FIG. **1**;

FIG. **4** is an exploded perspective view of the liner assembly of FIG. **1**, including an upper liner and a lower liner;

FIG. **5** is a perspective of the lower liner of FIG. **4**;

FIG. **6** is a perspective of the upper liner of FIG. **4**;

FIG. **7** is a perspective of the assembled liner assembly of FIG. **4**;

FIG. **8** is another perspective of the assembled liner assembly of FIG. **4**;

FIG. **9** is another perspective of the upper liner of FIG. **4**; and

FIG. **10** is a perspective of another embodiment of a lower liner that may be used in the liner assembly of FIG. **4**.

Like reference symbols used in the various drawings indicate like elements.

DETAILED DESCRIPTION

A chemical vapor deposition (CVD) system is indicated generally at **10** in FIG. **1**. The CVD system **10** includes a processing chamber **12** for depositing and/or growing thin films on a substrate **14** (e.g., a semiconductor wafer), a gas injecting port **16** disposed at one end of the processing chamber **12**, and a gas discharge port **18** disposed at an opposite end of the processing chamber **12**. In operation, a gas **20** is introduced into a processing volume **22** enclosed by an upper window **24** and a lower window **26** through the gas injecting port **16**. The gas **20** flows over the substrate surface **28** and reacts with the substrate surface **28**, or precursors disposed thereon, to deposit a film on the substrate surface **28**. The gas **20** then flows out of the processing volume **22** through the gas discharge port **18**. The CVD system also includes heating elements **30** (e.g., infrared heating lamps) for heating the substrate, and a preheating ring **32** for confining gas **20** to an upper portion **58** of the processing volume.

The substrate **14** upon which the film is deposited is supported by a susceptor **34** within the processing volume **22**. The susceptor **34** is connected to a motorized shaft **36**, which rotates the susceptor **34** (thereby rotating the substrate **14**) during the CVD process. The outer rim **38** of the susceptor is substantially flush with the substrate surface **28** when the substrate **14** is placed on the susceptor **34**.

The upper and lower windows **24**, **26** each comprise a generally annular body made of quartz. The windows **24**, **26** may be planar, or, as shown in FIG. **1**, the windows **24**, **26** may have a generally dome-shaped configuration. Alternatively, one or both of the windows **24**, **26** may have an inwardly concave configuration. The upper and lower window **24**, **26** are coupled to the upper and lower chamber walls **40**, **42** of the processing chamber **12**, respectively.

The upper and lower chamber walls **40**, **42** define the outer perimeter of the processing chamber **12**, and abut the gas injecting port **16** and the gas discharge port **18**. In some embodiments, the gas injecting port **16** may be divided into two or more inject zones by one or more dividing walls (not shown) disposed within the gas injecting port **16** and extending in the direction of gas flow. Flow controllers, such as mass flow controllers, (not shown) in fluid communication with the inject zones are used to adjust the gas flow rate in the different inject zones. The flow controllers may be operated independently of one another, thereby permitting different gas flow rates in the different inject zones.

A baffle plate **44** is disposed between the upper and lower chamber walls **40**, **42** where the gas injecting port **16** abuts the chamber walls **40**, **42**. The baffle plate **44** has a generally elongate planer shape, and has a plurality of holes formed therein and distributed along the length of the body of baffle plate **44** to permit passage of gas **20** therethrough.

To prevent reactions between the gas **20** and the chamber walls **40**, **42** (which are typically fabricated from metallic materials, such as stainless steel), a plurality of liners **46**, **48** and inserts **50**, **52** are disposed within the processing chamber **12**. The liners **46**, **48** and inserts **50**, **52** are fabricated from suitable material such as quartz, or more specifically fused quartz manufactured from high-purity silica powder. The quartz suitably does not react with the gas **20**.

An inject insert **50** is disposed between the upper and lower chamber walls **40**, **42**, adjacent to the baffle plate **44** and the upper and lower liners **46**, **48**. The inject insert **50** defines a passageway **54** for the gas **20** from the gas injecting port **16** to a channel **140** (FIG. **2**) defined by the upper and lower liners **46**, **48**. In some embodiments, the inject insert **50** may be divided into two or more inject insert zones by one or more dividing walls (not shown) disposed within the inject insert **50** and extending the length of the inject insert **50** in a direction perpendicular to the baffle plate **44**.

As shown in FIGS. **4-6**, the upper liner **46** and the lower liner **48** each have an annular body made of suitable material, such as quartz or fused quartz manufactured from high-purity silica powder. The lower liner **48** is disposed in a lower portion **56** of the processing volume **22** adjacent the lower chamber walls **42**. The upper liner **46** is at least partially disposed in an upper portion **58** of the processing volume **22** adjacent the upper chamber walls **40**. The upper and lower liners **46**, **48**, collectively referred to herein as a liner assembly, act as liners between the chamber walls **40**, **42** and the processing volume **22** (FIG. **1**) to prevent reactions between the gas **20** and the chamber walls **40**, **42**.

The lower liner **48** (also referred to herein as a first liner) includes an outer peripheral surface **102**, an upper surface **104**, and an inner peripheral surface **106**. The upper surface **104** includes an outer peripheral edge **108** (also referred to herein as a circumferential edge) that extends around a portion of the outer peripheral surface **102**, and defines an imaginary outer peripheral line **110** (also referred to herein as a circumferential line) as shown in FIGS. **2-5**. The upper surface **104** of the lower liner **48** engages a lower surface **124** of the upper liner **46** when disposed within the processing chamber **12**.

The outer peripheral surface **102** includes a curved lower fluid guide **112** (also referred to herein as a first fluid guide) for directing incoming gas **20** from the inject insert passageway **54** to the processing volume **22**. The fluid guide **112** includes a first portion **114** and a second portion **116**. The first portion **114** is concave about the imaginary outer peripheral line **110** of the lower liner **48**, and the second portion **116** is convex about the imaginary outer peripheral line **110**. Each portion **114**, **116** of fluid guide **112** has a corresponding radius of curvature **114*r***, **116*r***

The radius of curvature **114*r*** is selected such that the surface of the lower fluid guide **112** is substantially flush with the inject insert **50** where the lower liner **48** abuts the inject insert **50**, as shown in FIG. **3**. The radius of curvature **116*r*** is selected such that the surface of the lower fluid guide **112** is substantially flush with the preheating ring **32** where the lower liner **48** abuts the preheating ring **32**, as shown in FIG. **3**.

In the embodiment shown in FIG. **3**, the radiuses of curvature **114*r***, **116*r*** are selected such that the first portion **114** and the second portion **116** are adjoining (i.e., directly connected to one another). As a result, the lower fluid guide **112** is a continuously curved surface. In other embodiments, the radiuses of curvature **114*r***, **116*r*** may be selected so that the first portion **114** and second portion **116** are connected by a linearly sloped portion disposed between the first portion **114** and second portion **116**.

In the embodiment shown in FIG. **3**, the radius of curvature **114*r*** is equal to the radius of curvature **116*r***. In other embodiments, the radius of curvature **114*r*** may be greater than, or less than, the radius of curvature **116*r***.

In the illustrated embodiment, the radiuses of curvature **114*r***, **116*r*** are between 5 millimeters and 27 millimeters, more specifically between 10 millimeters and 20 millimeters, and, more specifically, the radiuses of curvature **114*r***, **116*r*** are both 15.7 millimeters.

The upper liner **46** (also referred to herein as a second liner) includes an outer rim **118**, an inner rim **120**, a top **122** and a lower surface **124** that engages the upper surface **104** of the lower liner **48** when disposed within the processing chamber **12**. The upper liner **46** also includes an outer peripheral edge **126** adjoining the outer rim **118** and top **122**, and extending around the perimeter of the outer rim **118**. The upper liner **46** also includes a curved upper fluid guide **128** (also referred to herein as a second fluid guide) extending between the outer rim **118** and the inner rim **120**. The upper fluid guide **128** is contoured to complement the lower fluid guide **112** (i.e., the upper fluid guide **128** has a shape complementary to the lower fluid guide **112**). The upper fluid guide **128** includes a first portion **130** that is concave about the outer peripheral edge **126**, and a second portion **132** that is convex about the outer peripheral edge **126**. When the liners **46**, **48** are positioned within the processing chamber **12**, the first portion **130** of the upper fluid guide **128** is concave about the imaginary outer peripheral line **110** of the lower liner **48**, and the second portion **132** of the upper fluid guide **128** is convex about the imaginary outer peripheral line **110**, as shown in FIG. **2**. Each portion **130**, **132** of fluid guide **128** has a corresponding radius of curvature **130***r*, **132***r*.

The radiuses of curvature **130***r*, **132***r* are selected such that upper fluid guide **128** complements the lower fluid guide **112**, as shown in FIG. **3**.

The radius of curvature **130***r* is selected such that the surface of the upper fluid guide **128** is substantially flush with the inject insert **50** where the upper liner **46** abuts the inject insert **50**, as shown in FIG. **3**. The radius of curvature **132***r* is selected such that the surface of the upper fluid guide **128** is substantially perpendicular to the inner rim **120** where the upper fluid guide **128** adjoins the inner rim **120**, as shown in FIG. **3**.

In the embodiment shown in FIG. **3**, the radiuses of curvature **130***r*, **132***r* are selected such that the first portion **130** and the second portion **132** are adjoining (i.e., directly connected to one another). As a result, the upper fluid guide **128** is a continuously curved surface. In other embodiments, the radiuses of curvature **130***r*, **132***r* may be selected so that the first portion **130** and second portion **132** are connected by a linearly sloped portion disposed between the first portion **130** and second portion **132**.

In the embodiment shown in FIG. **3**, the radius of curvature **130***r* is equal to the radius of curvature **132***r*. In other embodiments, the radius of curvature **130***r* may be greater than, or less than, the radius of curvature **132***r*.

In the illustrated embodiment, the radiuses of curvature **130***r*, **132***r* are between 5 millimeters and 27 millimeters, more specifically between 10 millimeters and 20 millimeters, and, more specifically, the radiuses of curvature **130***r*, **132***r* are both 15.7 millimeters.

As shown in FIGS. **6** and **7**, the fluid guide **128** of the upper liner **46** includes a plurality of partition walls **134***a*, **134***b*, **134***c* extending outwardly from the surface of the fluid guide **128**. Each partition wall **134***a*, **134***b*, **134***c* has vertically extending sides **136** and a lower surface **138** extending between the sides **136** of a respective partition wall **134***a*, **134***b*, **134***c*. The lower surface **138** of each partition wall **134***a*, **134***b*, **134***c* is contoured to match the contours of the lower fluid guide **112** (i.e., the lower surfaces **138** of the partition walls **134***a*, **134***b*, **134***c* have a shape complementary to the lower fluid guide **112**). The embodiment shown in FIGS. **4** and **6** has a total of eight partition walls, including two outer partition walls **134***a*, four inner partition walls **134***b*, and two central partition walls **134***c*, although other embodiments may have at least 3, 4, 5, 6, or 7 partition walls, and up to 10, 12, 14, 16, 18, 20, or 22 partition walls. The partition walls **134***a*, **134***b*, **134***c* may be evenly distributed or spaced across the fluid guide **128** such that the distance between adjacent partition walls is the same for each pair of adjacent partition walls.

Alternatively, the spacing between partition walls **134***a*, **134***b*, **134***c* may vary. The partition walls **134***a*, **134***b*, **134***c* may be unevenly spaced such that the partition walls **134***a*, **134***b*, **134***c* are aligned with the dividing walls disposed within inject insert **50**. In the embodiment shown in FIGS. **4** and **6-9**, the outer and inner partition walls **134***a*, **134***b* are spaced an equal distance apart and the central two partition walls **134***c* are spaced apart by a distance greater than the outer and inner partition walls **134***a*, **134***b*.

The partition walls **134***a*, **134***b*, **134***c* extend outwardly from the fluid guide **128** a predetermined distance such that the lower surfaces **138** of the partition walls **134***a*, **134***b*, **134***c* are substantially flush with the surface of the lower fluid guide **112** when the upper and lower liners **46**, **48** are positioned within the processing chamber **12**. Thus, when the upper and lower liners **46**, **48** are positioned within the processing chamber **12**, channels **140** are formed through which the incoming gas **20** flows before entering the processing volume **22**.

The channels **140** are defined by the surface of the upper fluid guide **128**, the surface of the lower fluid guide **112**, and the sides **136** of adjacent partition walls **134***a*, **134***b*, **134***c*. As the incoming gas **20** enters a channel **140**, the lower fluid guide **112** provides a smooth, continuous surface between the inject insert **50** and the lower fluid guide **112**, and gradually directs the gas **20** upwards towards the upper fluid guide **128**. The adjacent partition walls **140** prevent the gas **20** from flowing outwardly in a circumferential direction along the fluid guide **112**. As the incoming gas **20** moves further into channel **140**, the upper fluid guide **128** gradually redirects upward flowing gas **20** towards processing chamber **12**. As the gas **20** flows out of channel **140** and into the processing chamber **12**, the lower fluid guide **112** provides a smooth, continuous surface between preheating ring **32** and lower fluid guide **112**.

The curved surface of the lower fluid guide **112** provides a smooth, continuous surface over which the incoming gas **20** flows compared to a stepped wall or a linearly sloped wall, which have abrupt changes that tend to disrupt incoming gas flow and create “dead spots” on the substrate surface **28**. The upper fluid guide **128** further reduces disruptions in the incoming gas flow by providing an additional contoured surface to direct the incoming gas **20** into the processing chamber **12**. The curved fluid guides **128**, **112** of the upper and lower liners **46**, **48** thereby reduce disruptions in gas flow, and thus provide a more uniform gas flow rate over the substrate surface **28**. As a result, the film deposited on the substrate **14** has a more uniform film thickness compared to films grown using liners with stepped or linearly sloped fluid guides. By reducing disruptions in gas flow, the curved fluid guides **128**, **112** permit higher gas flow rates to be used within the CVD system, thereby reducing processing time and increasing the throughput of CVD systems.

Additionally, because the curved surfaces of the upper and lower fluid guides **128**, **112** reduce disruptions in the incoming gas flow, the dependency of the flow rate distribution on the incoming gas flow rate and gas type is also reduced. As a result, it is not necessary to tune the CVD system every time the incoming gas flow rate or gas type is modified.

Referring now to FIG. **8**, the upper and lower liners **46**, **48** also define peripheral channels **142** when positioned within the processing chamber **12**. The peripheral channels **142** guide gas **20** to the outer edges of the substrate **14**, thereby ensuring a relatively uniform film thickness across the entire substrate surface **28**. The peripheral channels **142** are located adjacent to the outer partition walls **134***a*, and extend circumferentially around the upper and lower liners **46**, **48**. As shown in FIGS. **6** and **8-9**, each peripheral channel **142** is defined by the upper surface **104** of the lower liner **48**, one of the sides **136** of a respective outer partition wall **134***a*, an inner surface **144** of the outer rim **118**, an outer surface **146** of the inner rim **120**, the lower surface **148** of the top **122** of the upper liner **46**, and a lateral sidewall **150** extending between the inner rim **120** and the outer rim **118**.

In operation, incoming gas **20** flowing through the outermost channels **140** will be directed upwards and into the peripheral channels **142** by the lower fluid guide **112**. The inner surface **144** of the outer rim **118** and the outer surface **146** of the inner rim **120** will guide the gas **20** towards the lateral sidewall **150**. As the gas **20** fills the peripheral channels **142**, the gas **20** will flow out of the peripheral channels **142** and around the edges of the substrate **14** in the processing volume **22**. By directing gas flow to the outer edges of the substrate **14**, the upper and lower liners **46**, **48** contribute to a more uniform flow rate across the substrate surface **28**, and thus a more uniform film thickness of the deposited film.

FIG. **10** shows an alternative embodiment of a lower liner **1048** comprising a modular assembly. A fluid guide **1012** substantially identical to fluid guide **112** is included in a lower liner insert **1050** that fits within a recess **1052** defined within the annular body of the lower liner **1048**. The lower liner insert **1050** includes a bow-shaped body and is sized to be received within the recess **1052**. The lower liner insert **1050** includes an outer peripheral surface **1054** that includes the curved fluid guide **1012**. With the exception of the lower liner insert **1050**, the lower liner **1048** of this embodiment is identical to the lower liner **1048** of FIGS. **4-5** and **7-8**. The lower liner **1048** includes an outer peripheral surface **1002**, an upper surface **1004**, and an inner peripheral surface **1006**. The upper surface **1004** includes an outer peripheral edge **1008** that extends around a portion of the outer peripheral surface **1002**, and defines an imaginary outer peripheral line **1010** as shown in FIG. **10**. The fluid guide **1012** includes a first portion **1014** and a second portion **1016**. The first portion **1014** is concave about the imaginary outer peripheral line **1010** of the lower liner **1048**, and the second portion **1016** is convex about the imaginary outer peripheral line **1010**.

The embodiments described herein are generally suitable for processing semiconductor or solar-grade wafers, though may be used in other applications. The embodiments described herein are particularly suitable for use in atmospheric-pressure silicon on silicon chemical vapor deposition epitaxy using gas mixtures including hydrogen, trichlorosilane, and diborane. Silicon precursors other than tricholorosilane may also be used with the embodiments described herein, including dichlorosilane, silane, trisilane, and tetrachlorosilane. Dopant gas species other than diborane may be used, including phosphene and arsine. The embodiments described herein may also be used in processes other than atmospheric-pressure silicon on silicon epitaxy, including reduced-pressure epitaxy, silicon-germanium epitaxy, carbon-doped silicon epitaxy, and non-epitaxial chemical vapor deposition.

As described above, liner assemblies of the present disclosure provide an improvement over known liner assemblies. The liner assembly avoids problems associated with stepped or linearly sloped liner systems, namely disruption of the incoming gas flow rate and “dead spots” on the substrate surface. These problems are avoided by providing curved upper and lower fluid guiding channels.

Additionally, the liner assembly includes peripheral channels that guide incoming gas to the outer edges of the substrate, thereby providing a more uniform gas flow rate over the substrate surface.

When introducing elements of the present invention or the embodiment(s) thereof, the articles “a”, “an”, “the” and “said” are intended to mean that there are one or more of the elements. The terms “comprising”, “including” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

As various changes could be made in the above constructions and methods without departing from the scope of the invention, it is intended that all matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A liner assembly for a substrate processing system, the liner assembly comprising:

a first liner including an annular body and an outer peripheral surface including a first fluid guide, the first fluid guide including a first surface rounded about a circumferential line extending around the first liner; and

a second liner including an annular body, an outer rim, an inner rim, a second fluid guide extending between the outer rim and the inner rim, and a plurality of partition walls extending outwardly from the second fluid guide, the second fluid guide including a second surface rounded about the circumferential line when the first and second liners are positioned within the processing system, wherein the second surface is opposite the first surface such that a rounded fluid guiding channel is defined between the first surface and the second surface, wherein the first fluid guide is a continuously rounded surface, wherein the second liner includes between three partition walls and twenty-two partition walls.

2. A liner assembly as set forth in claim **1** wherein the first liner is configured to be received in a lower portion of the processing system, and the second liner is configured to be at least partially received in an upper portion of the processing system.

3. A liner assembly as set forth in claim **1** wherein the second fluid guide has a shape complementary to the first fluid guide.

4. A liner assembly as set forth in claim **1** wherein a first portion of the first fluid guide is concave and a second portion of the first fluid guide is convex.

5. A liner assembly as set forth in claim **4** wherein a first portion of the second fluid guide is concave and a second portion of the second fluid guide is convex.

6. A liner assembly as set forth in claim **5** wherein the annular body of the first liner includes an outer peripheral surface and an inner peripheral surface, the first fluid guide extends from the outer peripheral surface to the inner peripheral surface, the first portion and the second portion of the first fluid guide define the continuously rounded surface across an entire length of the first fluid guide, the annular body of the second liner includes an outer peripheral surface and an inner peripheral surface, the second fluid guide extends from the outer peripheral surface to the inner peripheral surface, the first portion and the second portion of the second fluid guide define a continuously rounded surface across an entire length of the second fluid guide.

7. A liner assembly as set forth in claim **1** wherein each partition wall includes a lower surface having a shape complementary to the first fluid guide.

8. A liner assembly as set forth in claim **1** in combination with a chemical vapor deposition system.

9. A liner assembly as set forth in claim **1** further comprising a peripheral channel at least partially defined by an upper surface of the first liner, an inner surface of the outer rim, an outer surface of the inner rim, a lower surface of the second liner, and a sidewall extending between the inner rim and the outer rim.

10. A liner assembly as set forth in claim **1** wherein the first fluid guide is disposed on a removable insert configured to be received within a recess defined within the body of the first liner.

11. A liner assembly as set forth in claim **1** wherein the second fluid guide includes a continuously rounded surface.

12. A liner assembly as set forth in claim **1** wherein the annular body of the first liner includes an outer peripheral surface and an inner peripheral surface, the first fluid guide extends from the outer peripheral surface to the inner peripheral surface and the continuously rounded surface extends between the outer peripheral surface and the inner peripheral surface, the annular body of the second liner includes an outer peripheral surface and an inner peripheral surface, the second fluid guide extends from the outer peripheral surface to the inner peripheral surface and is a continuously rounded surface extending between the outer peripheral surface and the inner peripheral surface.

13. A liner assembly as set forth in claim **1** wherein the second liner includes twenty-two partition walls.

14. A liner assembly as set forth in claim **1** wherein the second liner includes eight partition walls.

15. A liner assembly as set forth in claim **14** wherein the second liner includes two outer partition walls, four inner partition walls, and two central partition walls.

16. A liner assembly as set forth in claim **15** wherein the outer partition walls, the inner partition walls, and the central partition walls are evenly spaced such that a distance between adjacent partition walls is the same for each pair of adjacent partition walls.

17. A liner assembly as set forth in claim **16** wherein an outer partition wall of the two outer partition walls is spaced apart from an inner partition wall of the four inner partition walls a first distance, the central partition walls are spaced apart from each other a second distance greater than the first distance.

18. A liner assembly as set forth in claim **1** wherein each partition wall extends from the second fluid guide a predetermined distance such that a lower surface of each partition wall is substantially flush with a surface of the first fluid guide.

19. A liner assembly as set forth in claim **18** wherein a plurality of channels are defined by the first fluid guide, the second fluid guide, and the plurality of partition walls.

20. A liner assembly for a substrate processing system, the liner assembly comprising:

a first liner including an annular body including a first fluid guide including a first surface having a concave portion having a radius of curvature and a convex portion having a radius of curvature, the annular body includes an outer peripheral surface and an inner peripheral surface, the first fluid guide extends from the outer peripheral surface to the inner peripheral surface; and

a second liner including a second fluid guide including a second surface having a concave portion and a convex portion, the first and second liners configured to engage one another such that the first and second fluid guides form at least one fluid guiding channel between the first surface and the second surface, wherein the first fluid guide is a continuously rounded surface extending between the outer peripheral surface and the inner peripheral surface.

21. A liner assembly as set forth in claim **20** wherein the second fluid guide has a shape complementary to the first fluid guide.

22. A chemical vapor deposition system as set forth in claim **21** further comprising a peripheral channel in fluid communication with the processing volume, the peripheral channel at least partially defined by an upper surface of the first liner, an inner surface of the outer rim, an outer surface of the inner rim, a lower surface of the second liner, and a sidewall extending between the inner rim and the outer rim.

23. A liner assembly as set forth in claim **20** wherein the concave portion of the first fluid guide has a radius of curvature between 5 millimeters and 27 millimeters, and the convex portion of the first fluid guide has a radius of curvature between 5 millimeters and 27 millimeters.

24. A liner assembly as set forth in claim **20** wherein the concave and convex portions of the first fluid guide adjoin one another.

* * * * *