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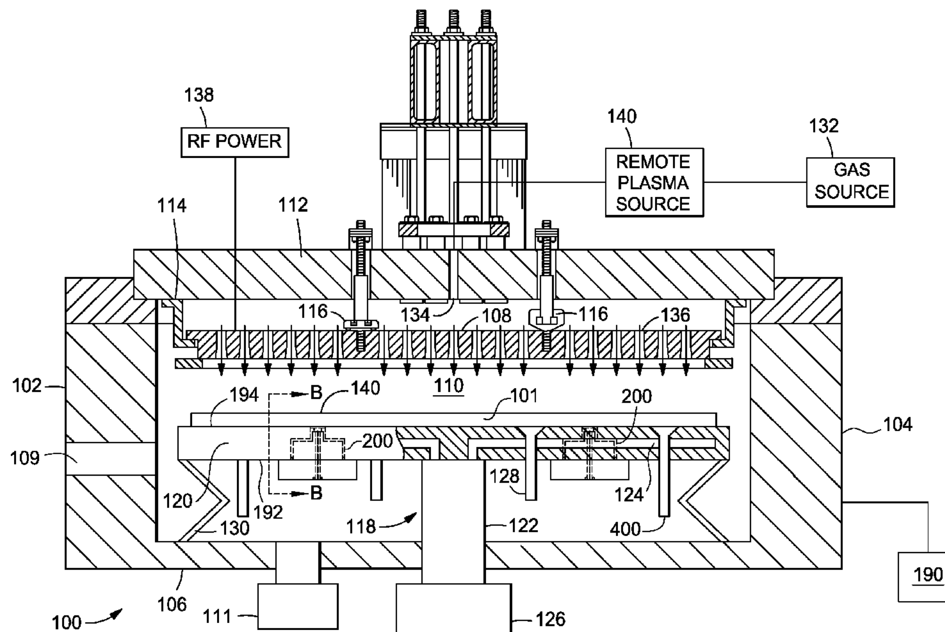

FIG. 1

(57) Abstract: Embodiments disclosed herein generally relate to a substrate temperature monitoring system in a substrate support assembly. In one embodiment, the substrate support assembly includes a support plate and a substrate temperature monitoring system. The support plate has a top surface configured to support a substrate. The substrate temperature monitoring system is disposed in the substrate support plate. The substrate temperature monitoring system is configured to measure a temperature of the substrate from a bottom surface of the substrate. The substrate temperature monitoring system includes a window, a body, and a temperature sensor. The window is integrally formed in a top surface of the support plate. The body is embedded in the support plate, through the bottom surface. The body defines an interior passage. The temperature sensor is disposed in the interior passage beneath the window. The temperature sensor is configured to measure the temperature of the substrate.

[Continued on next page]

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SUBSTRATE TEMPERATURE MONITORING

BACKGROUND

Field

[0001] Embodiments described herein generally relate to a substrate temperature monitoring system.

Description of the Related Art

[0002] Flat panel displays (FPD) are commonly used for active matrix displays such as computer and television monitors, personal digital assistants (PDAs), and cell phones, as well as solar cells and the like. Plasma enhanced chemical vapor deposition (PECVD) may be employed in flat panel display fabrication to deposit thin film on a substrate. PECVD is generally accomplished by executing a precursor gas into a plasma within a vacuum process chamber and depositing a film on a substrate from the excited precursor gas.

[0003] During deposition, the plasma within the vacuum processing chamber heats the substrate and the substrate support assembly. The plasma may cause the temperature of the substrate support assembly to have a temporal temperature increase or spike (e.g., about 30-50° C. increase, or 20%-30% temperature increase from 150° C.). Such a large temperature increase of the substrate support assembly undesirably causes process variation.

[0004] Thus, there is a need for an improved substrate temperature monitoring system for a substrate support assembly.

SUMMARY

[0005] Embodiments disclosed herein generally relate to a substrate temperature monitoring system in a substrate support assembly. In one embodiment the substrate support assembly is disclosed herein. The substrate support assembly includes a support plate and a substrate temperature monitoring system. The support plate has a top surface

configured to support a substrate. The substrate temperature monitoring system is disposed in the substrate support plate. The substrate temperature monitoring system is configured to measure a temperature of the substrate from a bottom surface of the substrate. The substrate temperature monitoring system includes a window, a body, and a temperature sensor. The window is integrally formed in a top surface of the support plate. The body is embedded in the support plate, through the bottom surface. The body defines an interior passage. The temperature sensor is disposed in the interior passage beneath the window. The temperature sensor is configured to measure the temperature of the substrate.

[0006] In another embodiment, a substrate support assembly is disclosed herein. The substrate support assembly includes a support plate and a substrate temperature monitoring system. The support plate has a top surface configured to support a substrate. The substrate temperature monitoring system is disposed in the support plate. The substrate temperature monitoring system is configured to measure a temperature of the substrate from a bottom surface of the substrate. The substrate temperature monitoring system includes a body, an aperture nut, a lens, an optical fiber tube, and a controller. The body defines an inner cavity. The aperture nut is disposed in the body. The lens is disposed in the body and supported by the aperture nut. The optical fiber tube is disposed in the inner cavity, spaced apart from the lens. The optical fiber tube is configured to receive an infra-red ray from the bottom of the substrate through the lens. The controller is in communication with the optical fiber tube. The controller is configured to determine the temperature of the substrate based on the received infra-red rays.

[0007] In another embodiment, a processing chamber is disclosed herein. The processing chamber includes a chamber body and a substrate support assembly. The chamber body includes a top wall, a sidewall, and a bottom wall defining a processing region in the chamber body. The substrate support assembly is disposed in the processing region. The substrate support assembly includes a support plate and a substrate temperature monitoring

system. The support plate has a top surface configured to support a substrate. The substrate temperature monitoring system is disposed in the support plate and is configured to measure a temperature of the substrate from a bottom surface of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0009] Figure 1 illustrates a cross-sectional view of a processing chamber having a substrate support assembly disposed therein, according to one embodiment.

[0010] Figure 2 illustrates a cross sectional view of the support plate of Figure 1, revealing a substrate temperature monitoring system, according to one embodiment.

[0011] Figure 3A illustrates a cross sectional view of the support plate of Figure 1, revealing a substrate temperature monitoring system, according to another embodiment.

[0012] Figure 3B illustrates a ray trace diagram 350 of the substrate temperature monitoring system, according to one embodiment.

[0013] Figures 4A-4B illustrate a substrate temperature monitoring system in the form of a lift pin, according to one embodiment

[0014] For clarity, identical reference numerals have been used, where applicable, to designate identical elements that are common between figures.

Additionally, elements of one embodiment may be advantageously adapted for utilization in other embodiments described herein.

DETAILED DESCRIPTION

[0015] Figure 1 illustrates a cross-sectional view of a processing chamber 100 having a substrate support assembly 118 that includes at least one temperature monitoring system, according to one embodiment. The processing chamber 100 may include a chamber body 102 having sidewalls 104, and a bottom 106 that define a processing volume 110. The processing volume 110 is accessed through an opening 109 formed through the sidewalls 104.

[0016] A showerhead 108 is disposed in the processing volume 110. The showerhead 108 may be coupled to a backing plate 112. For example, the showerhead 108 may be coupled to the backing plate 112 by a suspension 114 at the end of the backing plate 112. One or more coupling supports 116 may be used to couple the showerhead 108 to the backing plate 112 to aid in preventing sag.

[0017] The substrate support assembly 118 is also disposed in the processing volume 110. The substrate support assembly 118 includes a support plate 120 and a stem 122 coupled to the support plate 120. The support plate 120 is configured to support a substrate 101 during processing. The support plate 120 includes temperature control elements 124. The temperature control elements 124 are configured to maintain the substrate support assembly 118 at a desired temperature. The temperature control elements 124 run up through the stem 122 and extend below and across the entire upper surface of the support plate 120.

[0018] As noted above, the substrate support assembly 118 may include one or more substrate temperature monitoring systems 200, 300, and 400 disposed therein. The substrate temperature monitoring systems 200, 300, and 400 are configured to measure a temperature of the substrate 101 during processing. The substrate temperature monitoring systems 200-400 may be coupled to a proportional-integral-derivative (PID) controller 190. The PID controller 190 configured to continually read the temperature of the substrate

and adjust the amount of cooling fluid supplied to the temperature control elements 124. The substrate temperature monitoring systems 200-400 are discussed in more detail below, in conjunction with Figures 2-4B.

[0019] A lift system 126 may be coupled to the stem 122 to raise and lower the support plate 120. Lift pins 128 are moveably disposed through the support plate 120 to space the substrate 101 from the support plate 120 to facilitate robotic transfer of the substrate 101. The substrate support assembly 118 may also include RF return straps 130 to provide an RF return path at an end of the substrate support assembly 118.

[0020] A gas source 132 may be coupled to the backing plate 112 to provide processing gas through a gas outlet 134 in the backing plate 112. The processing gas flows from the gas outlet 134 through gas passages 136 in the showerhead 108. A vacuum pump 111 may be coupled to the chamber 100 to control the pressure within the processing volume 110. An RF power source 138 may be coupled to the backing plate 112 and/or to the showerhead 108 to provide RF power to the showerhead 108. The RF power creates an electric field between the showerhead 108 and the substrate support assembly 118 so that a plasma may be generated from the gases between the showerhead 108 and the substrate support assembly 118.

[0021] A remote plasma source 140, such as an inductively coupled remote plasma source, may also be coupled between the gas source 132 and the backing plate 112. Between processing substrates, a cleaning gas may be provided to the remote plasma source 140 so that a remote plasma is generated and provided into the processing volume 110 to clean chamber components. The cleaning gas may be further excited while in the processing volume 110 by power applied to the showerhead 108 from the RF power source 138. Suitable cleaning gases include but are not limited to NF_3, F_2, and SF_6.

[0022] Figure 2 illustrates a cross sectional view taken of the support plate 120 through section line B-B depicted in Figure 1, revealing the substrate temperature monitoring system 200, according to one embodiment. The substrate temperature monitoring system 200 includes a body 202 having an

interior passage 212 and a window 204. The body 202 is embedded in the support plate 120 through a bottom surface 192 of the support plate 120. In the embodiment shown in Figure 2, the body 202 is a hex-headed plug that is screwed into the support plate 120. One or more seals 210 may be positioned between the support plate 120 and the body 202 to seal the body 202 to the support plate 120.

[0023] The window 204 may be positioned below or flush with the top surface 194 of the support plate 120. The flush/recessed window 204 allows the substrate 101 to lay flat on the support plate 120. The window 204 may be formed from a transparent material. For example, the window 204 may be formed from sapphire, yttrium, or other suitable material.

[0024] The substrate temperature monitoring system 200 further includes a temperature sensor 206 and fiber tube 208. The temperature sensor 206 and fiber tube 208 are disposed in the interior passage 212 of the body 202. The temperature sensor 206 is disposed beneath the window 204, such that the temperature sensor 206 may measure a temperature of the substrate 101 during processing. The fiber tube 208 couples the temperature sensor 206 to the PID controller 190. The plurality of seals 210 may also be positioned between the fiber tube 208 and the body 202.

[0025] Figure 3A is a cross-sectional view of the support plate 120, revealing a substrate temperature monitoring system 300, according to one embodiment. The substrate temperature monitoring system 300 includes a body 302 defining an interior passage 304, a lens 306, an aperture nut 308, and an optical fiber tube 310. The body 302 is disposed in the support plate 120, beneath a tapped hole 312 formed in the support plate 120. The aperture nut 308 is disposed in the body 302. The aperture nut 308 is configured to hold the lens 306 in place. The aperture nut 308 includes a conical aperture 309 that is aligned with the lens 306. The optical fiber tube 310 is disposed in the interior passage 304, beneath the lens 306. For example, the optical fiber tube 310 is screwed into the body 302 using an SMA 905 connection on the optical fiber tube 310. The fiber tube 310 is configured to receive a focused IR beam coming from the bottom of the substrate 101 through the lens 306. The fiber tube 310 is coupled to PID

controller 190 that determines a temperature of the substrate 101 based on the received IR rays emitted from the bottom of the substrate 101.

[0026] In one embodiment, the lens 306 is a plano-convex lens, which focuses the IR rays emitting from the substrate 101 back to the fiber tube 310. The fiber tube 310 has an acceptance cone angle (or numerical aperture) requirement. For example, a 1000 μm fiber has an output divergence half angle of about 30 mRad, which corresponds to a half cone angle of 1.7 degrees, or full cone angle of 3.4 degrees. If the rays entering the fiber tube 310 from the substrate underfill or overfill the fiber tube 310, the transmission through the fiber tube 310 suffers, and thus, the detector will read a misrepresentation of the temperature (*i.e.,* low signal to noise ratio). The lens 306 enhances IR transmission by making sure that the IR rays entering the fiber tube 310 are within the acceptance cone of the fiber tube 310. Additionally, the tapped hole 312 formed in the support plate 120 has a conical shaped end 314. The conical shaped end 314 is configured to prevent IR beam clipping coming from the substrate. If the hole 312 was purely vertical, the light beam coming from the substrate 101 would be clipped, and hence, result in loss of signal.

[0027] The lens 306 may be formed from a transparent material. For example, in one embodiment, the lens 306 may be formed from MgF_2 (magnesium fluoride), CaF_2 (calcium fluoride), BaF_2 (barium fluoride), or Yr_2O_3 (crystalline yttria). The material of the lens 306 provides a sufficient chemical robustness to guard against the harsh cleaning agents used in a CVD process (e.g., an NF_3 cleaning agent, which is highly corrosive). Directly exposing the fiber tube 310 to NF_3 will gradually cause the fiber tube 310 to be etched away, thus reducing the effectiveness of signal transmission over time. The material of the lens 306 also exhibits enhanced transmission properties in the wavelength of interest (*i.e.,* 5- 15 μm). Thus, the lens 306 has superior performance compared to conventional lenses fabricated from an amorphous material transmitting infrared radiation (AMTIR). AMTIR is less chemically stable (*i.e.,* will be etched by NF_3 over a period of time) and also has less overall transmission (about 70%) as opposed to the materials from

which the lens 306 is fabricated, which has about 93% transmission in the same wavelength range.

[0028] The aperture in the aperture nut 308 is configured to reduce the numerical aperture of the incoming rays and maintain the numerical aperture of image side rays within the acceptance code of the fiber. O-rings 316 are positioned beneath the lens 306, which are configured to seal and, hence, prevent the fiber tube 310 from being attacked by NF_3 cleaning agent. The aperture nut 308 is also configured to provide the compressive force to squeeze the o-rings 316 into their grooves.

[0029] The aperture nut 308 is formed from a low-emissivity, polished material. The low emissivity material enhances the substrate temperature monitoring system 300 because when the support plate 120 becomes hot during the process, the body 302 and the aperture nut 308 will also become hot. Hot objects tend to emit IR radiation at certain temperatures. These IR rays would be collected by the optical fiber tube 310, resulting in false temperature readings. Thus, the low emissivity material ensures that the aperture nut 308 will not radiate a lot of heat.

[0030] Figure 3B illustrates an optical ray trace 350 of the substrate temperature monitoring system 300 in Figure 3A. Point A illustrates the location of the object, which is a bottom surface of the substrate 101. Point B illustrates the location of the aperture in the aperture nut 308, which is used to limit the numerical aperture of the object, and thus the numerical aperture of the image. Point C illustrates the location of the lens 306. Point D illustrates the location of the image. The optical fiber tube 310 is positioned at point D. The numerical aperture of the beam emerging from the lens 306 should match the numerical aperture of the optical fiber tube 310. Point E illustrates the location of the optical fiber tube 310, adjacent to point D. Point F illustrates the location of a focal point of the lens 306 on the object side. Point G illustrates the location of a focal point of the lens 306 on the image side. Points H and J illustrate the principal planes of the lens 306. The aperture at point B is placed between the object side focal point at point F and the first principal plane at point H. By doing so, the aperture will form a virtual image behind the lens 306, thus enhancing the temperature readings.

[0031] Figures 4A and 4B illustrate a substrate temperature monitoring system 400 in the form of lift pin 128, according to one embodiment. Figure 4A illustrates a cross-sectional view of the lift pin 128. The lift pin 128 includes a body 402 having an interior passage 404. The body 402 may include a rounded top surface 406 for contacting the substrate when in use.

[0032] The lift pin 128 further includes a temperature sensor 408, a fiber tube 410, and a cap 412. The temperature sensor 408 may be disposed in the interior passage 404 of the body 402. The cap 412 may be integrally formed with the top surface 406. The cap 412 is positioned about the temperature sensor 408, such that the cap 412 protects the temperature sensor 408 from contacting the substrate 101 or body 402. In one embodiment, such as that shown in Figures 4A-4B, the cap 412 may extend down an entire length, L, of the temperature sensor 408. The cap 412 may be formed from a conductive material, such as aluminum. The fiber tube 410 is disposed in the interior passage 404. The fiber tube 410 is configured to couple the temperature sensor 408 with the controller 190.

[0033] In operation, the lift pin 128 is configured to raise the substrate 101 off the top surface 194 of the support plate 120 by contacting the substrate 101 with the top surface 406 of the lift pin 128. Because the top surface 406 of the lift pin 128 is rounded, the cap 412 is the portion of the top surface 406 that contacts the bottom surface of the substrate 101. The temperature sensor 408 is configured to measure a temperature of the substrate 101 when the lift pin 128 is in contact with the substrate 101.

[0034] In another embodiment, the body 402 may include an opening 414 formed in a side of the body 402. The opening 414 allows the fiber tube 410 to exit the lift pin 128 through the side and couple the temperature sensor 408 to the PID controller 190. This ensures that the fiber tube 410 is not damaged when the substrate support assembly 118 is lowered and the lift pin 128 is displaced through contact with another object at the bottom of the pin 128, for example by the bottom surface 106 of the chamber 100 when the substrate support assembly 118 is lowered to a transfer position.

[0035] The substrate temperature monitoring system 400 provides a contact method of measuring and controlling the temperature of the substrate 101.

[0030] While the foregoing is directed to specific embodiments, other and further embodiments may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A substrate support assembly, comprising:

a support plate having a top surface configured to support a substrate; and

a substrate temperature monitoring system disposed in the substrate support plate, the substrate temperature monitoring system configured to measure a temperature of the substrate from a bottom surface of the substrate, the substrate temperature monitoring system comprising:

a window integrally formed in a top surface of the support plate;

a body embedded in the support plate, through the bottom surface, the body having an interior passage; and

a temperature sensor disposed in the interior passage beneath the window, the temperature sensor configured to measure to temperature of the substrate.

2. The substrate support assembly of claim 1, further comprising a fiber tube disposed in the interior passage, the fiber tube coupled to the temperature sensor.

3. The substrate support assembly of claim 2, wherein the fiber tube couples the temperature sensor with a PID controller.

4. A substrate support assembly, comprising:

a support plate having a top surface configured to support a substrate; and

a substrate temperature monitoring system disposed in the support plate, the substrate temperature monitoring system configured to measure a temperature of the substrate from a bottom surface of the substrate, the substrate temperature monitoring system, comprising:

a body defining an inner cavity;

an aperture nut disposed in the body;

a lens disposed in the body and supported by the aperture nut;

an optical fiber tube disposed in the inner cavity, spaced apart from the lens, the optical fiber tube configured to receive an infrared ray from the bottom surface of the substrate through the lens and

a controller in communication with the optical fiber tube, the controller configured to determine the temperature of the substrate based on the received infra-red rays.

5. The substrate support assembly of claim 4, wherein the lens is a plano-convex lens.

6. The substrate support assembly of claim 4, wherein the aperture nut includes a conical aperture that is aligned with the lens.

7. The substrate support assembly of claim 4, wherein the support plate further includes a tapped hole, and wherein the substrate temperature monitoring system is disposed beneath the tapped hole such that the lens is aligned with the tapped hole.

8. The substrate support assembly of claim 4, wherein the aperture nut is formed from a low-emissivity material.

9. The substrate support assembly of claim 4, wherein the optical fiber tube is disposed in the body at a location where an image is projected by the lens.

10. The substrate support assembly of claim 4, wherein the aperture nut is positioned at a distance from the lens that is less than a distance of a focal length of the lens.

11. The substrate support assembly of claim 4, further comprising:

a plurality of o-rings positioned beneath the lens, the plurality of o-rings configured to seal and prevent the optical fiber tube from being attacked by a cleaning agent.

12. A processing chamber, comprising:

a chamber body comprising a top wall, a sidewall, and a bottom wall defining a processing region in the chamber body; and

a substrate support assembly disposed in the processing region, the substrate support assembly comprising:

a support plate having a top surface configured to support a substrate; and

a substrate temperature monitoring system is disposed in the support plate and is configured to measure a temperature of the substrate from a bottom surface of the substrate.

13. The processing chamber of claim 12, wherein the substrate temperature monitoring system comprising:

a window integrally formed in a top surface of the support plate;

a body embedded in the support plate, through the bottom surface, the body defining an interior passage; and

a temperature sensor disposed in the interior passage beneath the window, the temperature sensor configured to measure to temperature of the substrate.

14. The processing chamber of claim 13, wherein the substrate temperature monitoring system further comprises:

a lens positioned between the window and the temperature sensor.

15. The processing chamber of claim 12, wherein the substrate temperature monitoring system is in the form of a lift pin, the substrate temperature monitoring system comprising:

a body defining an interior passage, the body having a rounded top surface;

a temperature sensor disposed in the interior passage, the temperature sensor configured to measure the temperature of the substrate; and

a cap integrally formed with the rounded top surface, the cap positioned about the temperature sensor, the cap configured to protect the temperature sensor from contacting the body.

FIG. 1

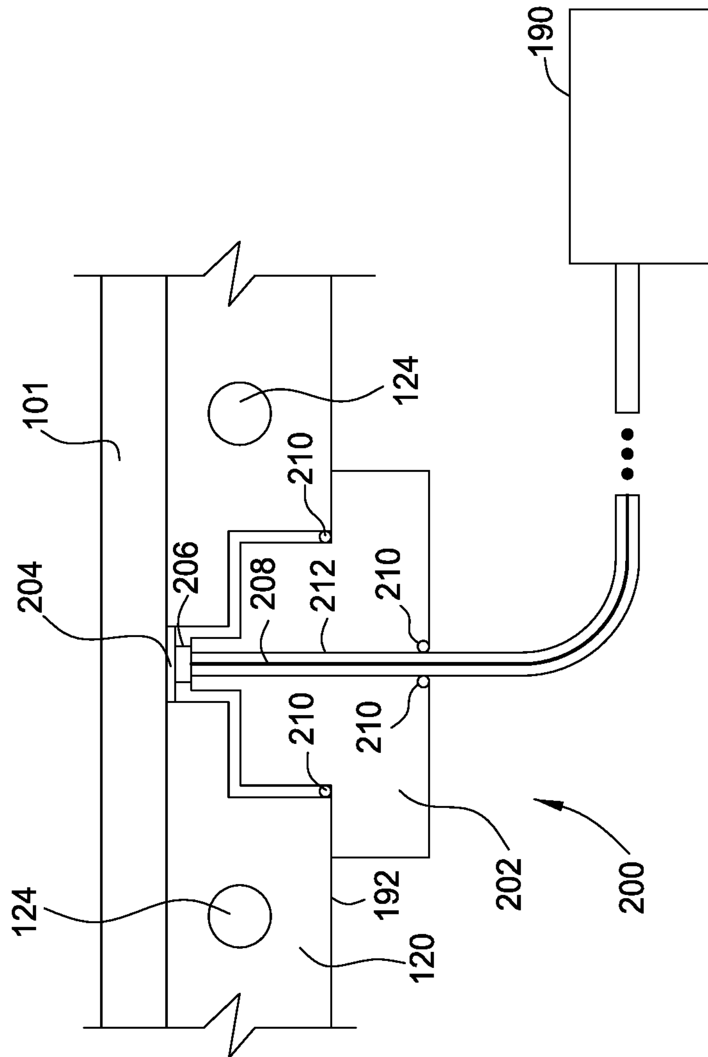

FIG. 2

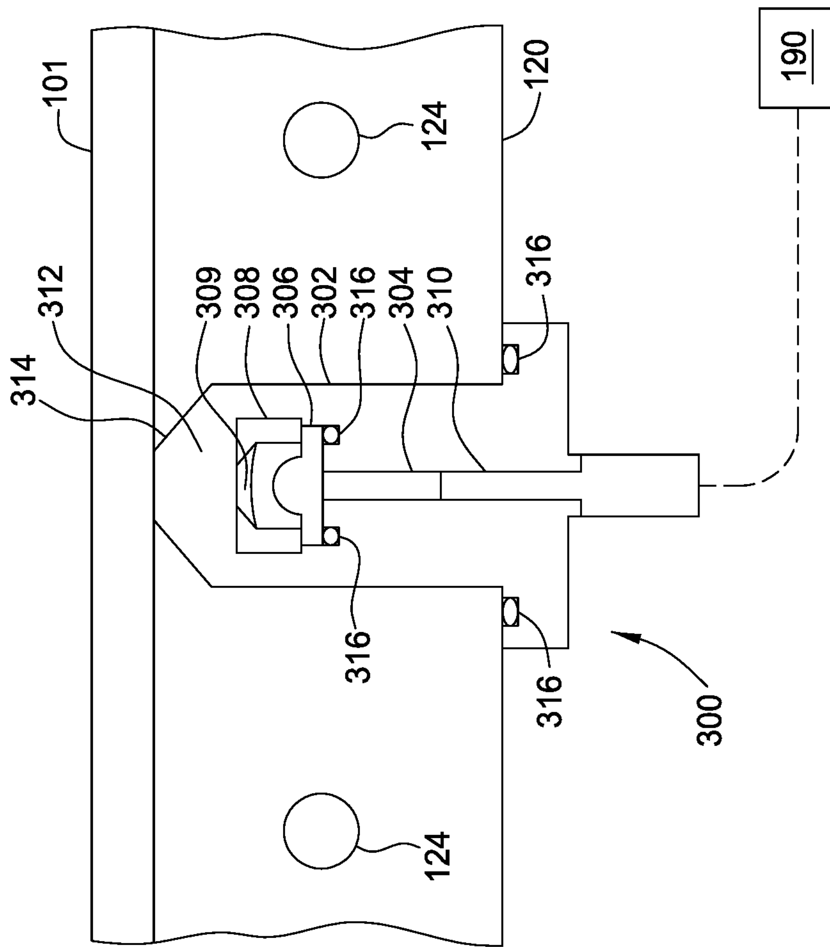

FIG. 3A

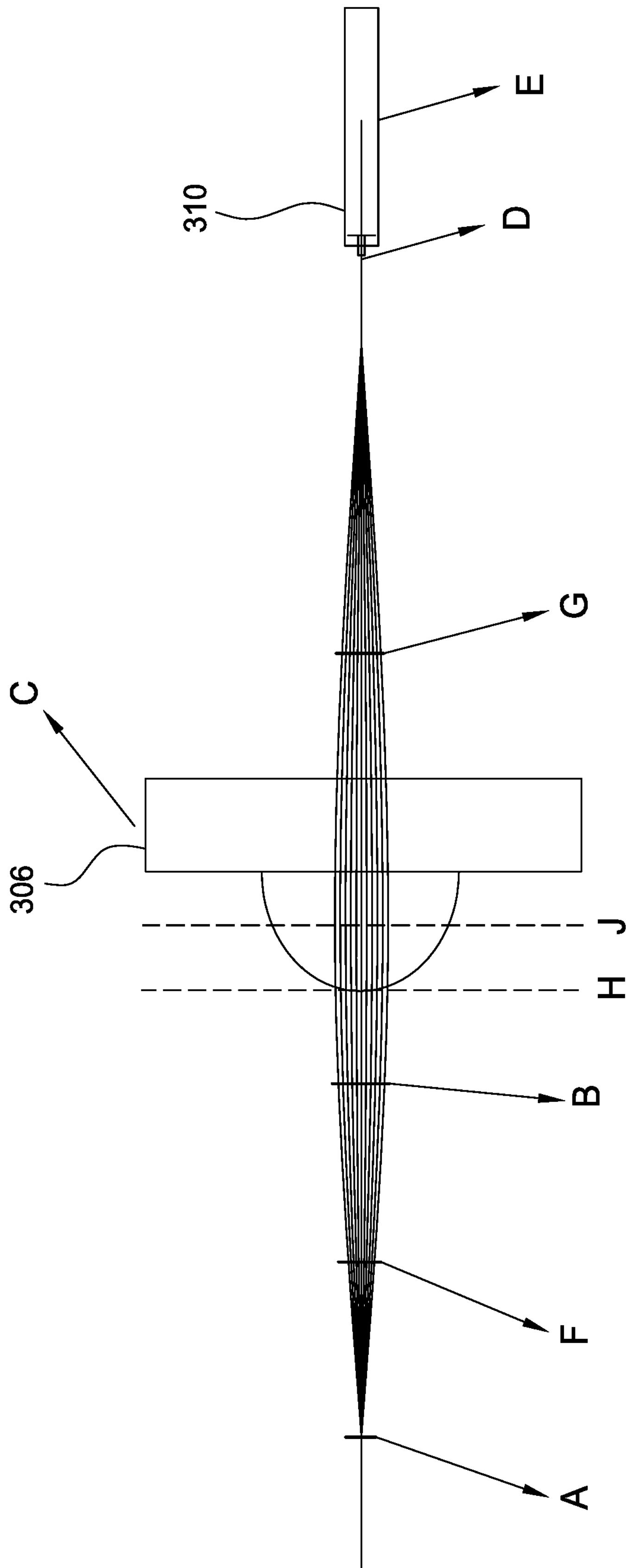

FIG. 3B

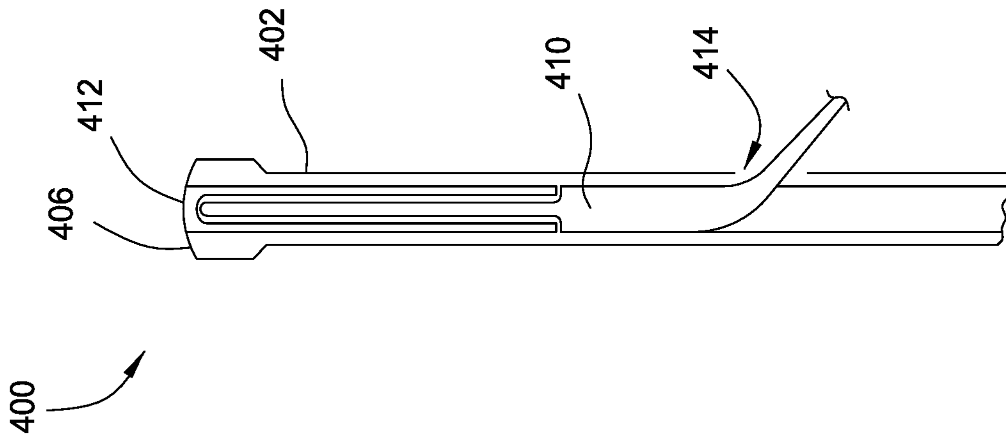

FIG. 4B

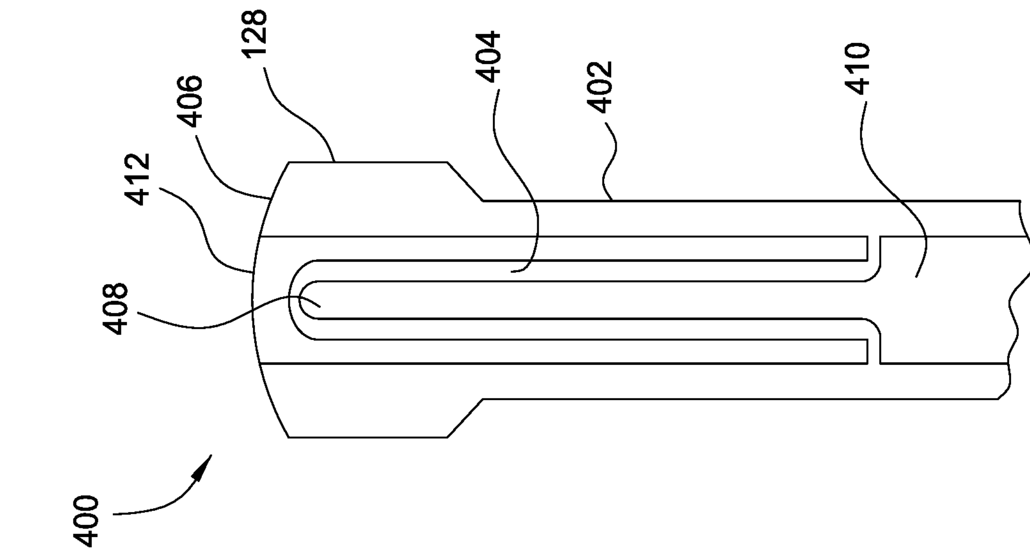

FIG. 4A

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/035988

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/67(2006.01)i, H01L 21/66(2006.01)i, H01L 21/02(2006.01)i, H01L 21/683(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/67; G01R 31/26; G01K 13/00; G01K 1/16; H01L 21/26; G01J 5/06; G01K 11/00; H01L 21/66; H01L 21/02; H01L 21/683

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: processing chamber, substrate support assembly, support plate, substrate temperature monitoring system, window, temperature sensor, controller, fiber tube, lens

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 11-258054 A (OMRON CORP.) 24 September 1999 See paragraphs [0018]-[0020], [0026]-[0030], claim 2, and figures 1, 3.	12
Y		1-11,13-15
Y	JP 2016-076529 A (TOKYO ELECTRON LTD.) 12 May 2016 See paragraphs [0029]-[0030], [0032], [0038] and figures 1, 4.	1-3,13-15
Y	US 2004-0004990 A1 (KHAN, ABID L.) 08 January 2004 See paragraph [0009] and figures 1-2.	4-11
Y	US 2003-0176000 A1 (OTSUBO et al.) 18 September 2003 See paragraph [0052] and figure 5.	11
A	US 5716133 A (HOSOKAWA et al.) 10 February 1998 See column 5, line 46 - column 6, line 67, column 11, lines 59-66 and figures 1, 3, 14.	1-15

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
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"P" document published prior to the international filing date but later than the priority date claimed
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
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Date of the actual completion of the international search
29 August 2017 (29.08.2017)

Date of mailing of the international search report
31 August 2017 (31.08.2017)

Name and mailing address of the ISA/KR
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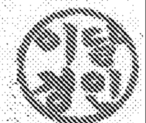

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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