



- (51) International Patent Classification:
H05B 3/40 (2006.01) *H05B 3/78* (2006.01)
- (21) International Application Number:
PCT/US2013/065196
- (22) International Filing Date:
16 October 2013 (16.10.2013)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
13/656,113 19 October 2012 (19.10.2012) US
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- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))



WO 2014/062777 A1

(54) Title: CARTRIDGE HEATER APPARATUS

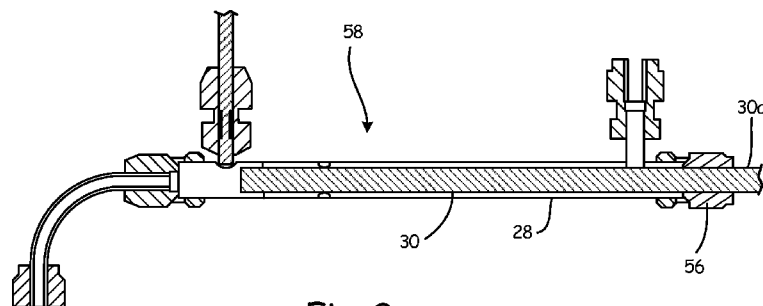


Fig. 3

(57) Abstract: A cartridge heater apparatus 50 includes a tube 28; a heating cartridge 30 adapted to be inserted into the tube 28 for heating fluid passing through a passage space between the heating cartridge 30 and the tube 28, the heating cartridge 30 being se- cured at a first end 30a thereof in a cantilever manner; and means 58 for supporting the heating cartridge 30 in the tube 28 at a loca- tion distant from the first end 30a, without blocking the fluid passing through the passage space between the heating cartridge 30 and the tube 28.

CARTRIDGE HEATER APPARATUS

BACKGROUND OF THE INVENTION

[0001] This invention relates to a cartridge heater apparatus, in which a heating cartridge is securely inserted into a tube for controllably heating the fluid passing through the tube.

[0002] A cartridge heater is typically constructed by an electrical resistor coated with a layer of insulation material that tends to be low in electrical conductivity, but high in thermal conductivity. In operation, the cartridge heater is connected to a power supply for the electrical resistor to convert the electric power provided by the power supply into heat. Among many shapes and forms the cartridge heater can be made into, a cylinder is one of the most popular, commercially-available configurations, which provides a convenient, point-of-use heating solution. For example, the cartridge heater can be easily inserted into a tube in a manner that a passage space between the cartridge heater and the inner wall of the tube is provided to enable a fluid stream to pass through, thereby absorbing the heat generated by the cartridge heater. This type of cylinder-shaped cartridge heater is often called the single-pass cartridge heater.

[0003] One of the areas, in which the single-pass cartridge heater can be applied, is semiconductor manufacturing. A system used in manufacturing semiconductor devices typically includes, among other things, a process tool, a vacuum pump arrangement having a booster pump and a backing pump, and an abatement device. The process tool typically includes a process chamber, in which a process step, such as Chemical Vapor Deposition (CVD), Atomic Layer Deposition (ALD), oxidation, ion implantation, etching, lithography, etc., takes place to construct a predetermined microstructure on a semiconductor substrate placed therein. The vacuum pump arrangement is connected to the process tool for evacuating the process chamber to create a vacuum environment required by the process step in the process chamber. The gas evacuated from the process chamber by the vacuum pump arrangement is typically directed to the abatement device connected to an exhaust outlet of the vacuum pump arrangement via a tube or pipeline. The abatement device destroys or

decomposes the harmful or toxic components of the gas exhausted from the vacuum pump arrangement, so as to make it safe to be released to the environment.

[0004] It is important that the temperature of the exhaust gas passing through the tube between the vacuum pump arrangement and the abatement device is kept in an appropriate range to ensure proper functioning of the abatement device and safety of the semiconductor manufacturing system. Conventionally, a single-pass cartridge heater is inserted into the tube for heating up the exhaust gas passing through the tube. In the tube, the single-pass cartridge heater is air-tightly secured by a nut at a first end of the cartridge heater. The single-pass cartridge heater extends inside and along the tube from the first end in a cantilever manner. The diameter of the single-pass cartridge heater is made smaller than the inner diameter of the tube, such that a passage space is formed between the single-pass cartridge heater and the tube. In operation, the gas exhausted from the vacuum pump arrangement is introduced into the tube and passes through the passage space into the abatement device. As the exhaust gas travels through the passage space, the single-pass cartridge heater is controlled to heat up the exhaust gas, so as to keep its temperature in an appropriate range.

[0005] There are drawbacks in the conventional design of the single-pass cartridge heater that might cause it to operate inefficiently or create safety hazards. For example, manufacturing tolerances for ensuring the single-pass cartridge heater to be properly fitted into the tube might cause an excessive contact between the cartridge heater and the tube. In some other instances, the single-pass cartridge heater may warp over time, leading to an excessive contact between the cartridge heater and the inner surface of the tube. Such excessive contact may render the single-pass cartridge heater to operate inefficiently, or even create safety hazards caused by the overheating of the tube.

[0006] Thus, what is needed is a cartridge heater apparatus capable of avoiding the excessive contact between the cartridge heater apparatus and the tube, thereby ensuring safety and efficient operation of the same.

BRIEF SUMMARY OF THE INVENTION

[0007] In accordance with some embodiments of the invention, a cartridge heater apparatus includes a tube; a heating cartridge adapted to be inserted into the tube for heating fluid passing through a passage space between the heating cartridge and the tube, the heating

cartridge being secured at a first end thereof in a cantilever manner; and means for supporting the heating cartridge in the tube at a location distant from the first end, without blocking the fluid passing through the passage space between the heating cartridge and the tube.

[0008] In accordance with some other embodiments of the invention, a system includes a process chamber; a vacuum pump arrangement connected to an outlet of the process chamber for evacuating fluid from the process chamber; an abatement device connected to an outlet of the vacuum pump arrangement via a tube for treating exhaust fluid emitted from the vacuum pump arrangement; a heating cartridge adapted to be inserted into the tube for heating the exhaust fluid passing through a passage space between the heating cartridge and the tube, the heating cartridge being secured at a first end thereof in a cantilever manner; and means for supporting the heating cartridge in the tube at a location distant from the first end, without blocking the exhaust fluid passing through the passage space between the heating cartridge and the tube.

[0009] The construction and method of operation of the invention, however, together with additional objectives and advantages thereof will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. 1 illustrates a schematic diagram showing a semiconductor manufacturing system in accordance with some embodiments of the present invention.

[0011] FIG. 2 illustrates a side view of a cartridge heater apparatus in accordance with some embodiments of the present invention.

[0012] FIG. 3 illustrates a cross-sectional view of the cartridge heater apparatus along an axial direction thereof in accordance with some embodiments of the invention.

[0013] FIG. 4 illustrates a cross-sectional view of the cartridge heater apparatus in a radial direction thereof in accordance with some embodiments of the invention.

[0014] FIG. 5 illustrates a cross-sectional view of another cartridge heater apparatus in a radial direction thereof in accordance with some embodiments of the invention.

[0015] FIG. 6 illustrates a cross-sectional view of yet another cartridge heater apparatus in a radial direction in accordance with some embodiments of the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present disclosure is directed to a cartridge heater apparatus, which includes without limitation a tube, and a heating cartridge adapted to be inserted into the tube for heating a fluid stream passing through the tube. When the heating cartridge is inserted into the tube, the heating cartridge is secured at a first end thereof in a cantilever manner. The cartridge heater apparatus is provided with means for supporting the heating cartridge in the tube at a location distant from the first end of the heating cartridge. This additional location of support prevents excessive contact between the heating cartridge and the inner wall of the tube that may be caused by the manufacturing tolerances of the heating cartridge or deformation of the same over time. As a result, the cartridge heater apparatus can be made safer by reducing or eliminating the hot surface areas of the tube caused by the excessive contact, which otherwise would have occurred if there had been no such supporting means. In addition, by eliminating or reducing the hot surface areas, the temperature distribution of the fluid stream in the tube can be more accurately controlled by adjusting the power supplied to the heating cartridge. This, in turn, leads to an improved operational efficiency for any processes in which the cartridge heater apparatus is used. For example, the cartridge heater apparatus can be used to keep the temperature of certain exhaust gases produced by a semiconductor manufacturing process in a desired range. One particular application of the cartridge heater apparatus is the semiconductor manufacturing process. It is noted that besides semiconductor manufacturing processes, the cartridge heater apparatus can be applied in any situations where a point-of-use, single-pass heating cartridge is needed to control the temperature of a fluid stream in a tube.

[0017] FIG. 1 illustrates a schematic view of a semiconductor processing system 10, in which a cartridge heater apparatus in accordance with some embodiments of the invention can be applied. The system 10 includes without limitation a process chamber 12 and a vacuum pump arrangement 20 connected thereto in series. The vacuum pump arrangement 20 draws gases out of the process chamber 12 and creates a vacuum environment in it to carry out certain processes, such as depositions, oxidation, etching, ion implantation, epitaxy,

lithography, etc. The gases can be introduced into the process chamber 12 from one or more gas sources, such as the ones designated by 14a and 14b in this figure. The gas sources 14a and 14b can be connected to the process chamber 12 via control valves 16a and 16b, respectively. The timing of introducing various gases into the process chamber 12 can be controlled by selectively turning on or off the control valves 16a and 16b. The flow rate of the gas introduced from the gas source 14a or 14b into the process chamber 12 can be controlled by adjusting the fluid conductance of the control valves 16a or 16b, respectively.

[0018] The vacuum pump arrangement 20 might include a booster pump 22 and a backing pump 24 connected together in series. The inlet of the booster pump 22 is connected to the outlet of the process chamber 12. The outlet of the booster pump 22 is connected to the inlet of the backing pump 24. The outlet of the backing pump 24 might be connected to an abatement device 26 where the exhaust gases emitted from the backing pump 24 are treated in order to reduce the harmful impact the exhaust gases might have on the environment. The abatement device 26 can be one of various types, such as a thermal processing unit, plasma reactor, microwave reactor, wet scrubber, or combination thereof.

[0019] A tube 28 is disposed between the outlet of the backing pump 24 and the inlet of the abatement device 26 as a conduit for the exhaust gases to flow from the backing pump 24 to the abatement device 26. A heating cartridge 30 can be inserted into the tube 28 in such a manner that there is sufficient passage space between the heating cartridge 30 and the tube 28 for the exhaust gases to pass from the backing pump 24 to the abatement device 26 without being blocked. The heating cartridge 30 can be constructed by at least one electrical resistor (not shown in the figure) enclosed by a layer of insulation material, which tends to be high in thermal conductivity and low in electrical conductivity. The heating cartridge 30 is electrically connected to a power supply 32, which powers the electrical resistor to generate heat. A thermal couple (not shown in the figure) can be attached to the tube 30 to generate a signal indicative of the temperature of the exhaust gas in the tube 28. The thermal couple can be electrically connected to a controller 34 to control the power provided by the power supply 32 to the heating cartridge 30 in response to the signal, thereby keeping the temperature of the exhaust gas in a desired range.

[0020] When the heating cartridge 30 is inserted in the tube 28, the heating cartridge 30 is secured at a first end thereof in a cantilever manner. Means is provided to support the heating cartridge 30 in the tube 28 at a location distant from the first end of the heating cartridge 30. The tube 28, heating cartridge 30, and supporting means are collectively referred to as the cartridge heater apparatus in this disclosure, regardless whether they are assembled together as a ready-to-use apparatus or separated in the form of a kit. The cartridge heater apparatus in this disclosure is also used to more broadly refer to a collection of any other components in support of or in addition to the tube 28, heating cartridge 30, and supporting means.

[0021] FIG. 2 illustrates a side view of a cartridge heater apparatus 50 in accordance with some embodiments of the present invention. The cartridge heater apparatus 50 includes without limitation the tube 28, which has an inlet 52 adapted to receive the exhaust gas from the backing pump 24 or from the vacuum pump arrangement 20 in cases where the backing pump 24 is omitted from the vacuum pump arrangement 20, and an outlet 54 adapted to emit the exhaust gas to the abatement device 26. Inside the tube 28, a heating cartridge 30 is inserted. Referring to FIGs. 2 and 3 simultaneously, the heating cartridge 30 is secured by a nut to the tube 28 in a cantilever manner at a first end designed by numeral 30a. The diameter of the heating cartridge 30 is smaller than the inner diameter of the tube 28, such that a passage space is formed between the heating cartridge 30 and the inner surface of the tube 28. Means 58 for supporting the heating cartridge 30 in the tube 28 is provided at a location distant from the first end 30a thereof, without blocking the passage space between the heating cartridge 30 and the tube 28. In some embodiments of the invention, the supporting means 58 takes the form of at least one recessed portion on an inner wall of the tube 28 in contact with the heating cartridge 30 inserted therein. It is noted that the supporting means 58 may take other forms as long as it holds the heating cartridge 30 in the tube 28, without blocking the passage space between the heating cartridge 30 and the inner surface of the tube 28. The inlet 52 is disposed at a location between the first end 30a of the heating cartridge 30 and the supporting means 58. As the first end 30a of the heating cartridge 30 is sealed by the nut 56, the exhaust gas emitted from the vacuum pump

arrangement 20 flows into the tube 28 via the inlet 52, through the passage space between the heating cartridge 30 and the tube 28, and out of the tube 28 via the outlet 54.

[0022] The heating cartridge 30 is constructed by a cylinder or otherwise shaped body enclosing an electrical resistor (not shown in the figures). The body is made of at least a material that is low in electrical conductivity but high in thermal conductivity. The electrical resistor is connected to the power supply 32 via a cable 60 and a connector 62. In operation, the electrical resistor generates heat to maintain or increase the temperature of the exhaust gas passing through the passage space between the heating cartridge 30 and the inner surface of the tube 28 at or to a predetermined level, thereby ensuring proper functioning of the abatement device 26 connected to the outlet 54 of the tube 28, and preventing undesired particulates generated from the exhaust gas due to a drop of temperature from being accumulated in the tube 28.

[0023] A thermal couple 70 is fluidly connected to the exhaust gas in the tube 28 via a tube 72. The thermal couple 70 can be plugged into the controller 34, or connected to the same via a connector. The thermal couple 70 generates a first signal indicative of the temperature of the exhaust gas in the tube 28. The controller 34 in turn controls the power supply 32 in response to the first signal received from the thermal couple 70. If the temperature of the exhaust gas exceeds a predetermined threshold, the controller 34 will direct the power supply 32 to cut off the power supplied to the heating cartridge 30, thereby preventing the exhaust gas in the tube 28 from overheating. In addition to the thermal couple 70, an over-temperature protection switch 74 can also be provided to protect the tube 28 from overheating. The over-temperature protection switch 74 is attached to the outer surface of the tube 28 and not in direct contact with the exhaust gas in the tube 28. The over-temperature protection switch 74 can be electrically connected to the controller 34 via a connector 78. The over-temperature protection switch 78 generates a second signal indicative of the temperature of the tube 28. If temperature of the tube 28 exceeds a predetermined threshold, the controller 34 will direct the power supply 32 to cut off the power supplied to the heating cartridge 30, thereby preventing the tube 28 from overheating. The over-temperature protection switch 74 protects the tube 28 from overheating even when there is insufficient amount of the exhaust gas in the tube 28 to trigger the thermal couple 70

to generate a signal that cuts off the power from the power supply 32 to the heating cartridge 30.

[0024] One of the advantages of the cartridge heater apparatus 50 in accordance with some embodiments of the invention is to avoid undesired, excessive contact between the heating cartridge 30 and the inner surface of the tube 28, thereby ensuring safety and efficient operation, which might be adversely affected by the tube 28 being overheated. The supporting means 58 supports the heating cartridge 30 at a location separate from the first end 30a thereof, and in addition to the nut 56 that secures the heating cartridge 30 in a cantilever manner. As such, any excessive contact between the body of the heating cartridge 30 and the inner surface of the tube 28 caused by manufacturing tolerances or warping of the heating cartridge 30 can be avoided.

[0025] FIGs. 4-6 illustrate various supporting means in accordance with some embodiments of the invention. FIG. 4 illustrates a cross-sectional view along the line C-C in FIG. 2. In FIG. 4, the supporting means 58 is configured in the form of a number of recessed portions on the inner wall of the tube 28. The number of the recessed portions 58a can vary depending on design choices. In some embodiments of the invention, three or more recessed portions 58a might be spread around the heating cartridge 30 at the same location in an axial direction of the tube 28 to support the heating cartridge 30. In some other embodiments of the invention, only one or two recessed portions 58a might be implemented to support the heating cartridge 30.

[0026] The recessed portions 58a can be integral parts of the tube 28 in some embodiments of the invention. The recessed portions 58a can be made by pressing the tube 28 with pointed forces to create dimples capable of holding the heating cartridge 30 in the tube 28. In some other embodiments of the invention, the recessed portions 58a can be made by attaching small objects to the inner surface of the tube 28.

[0027] FIG. 5 illustrates a cross-sectional view of supporting means 80 in accordance with some embodiments of the invention. In FIG. 5, the supporting means 80 is configured in the form of a number of protrusions 80a on the surface of the heating cartridge 30. The number of the protrusions 80a can vary depending on design choices. In some embodiments of the invention, three or more protrusions 80a might be spread around the heating cartridge

30 at the same location in an axial direction of the same. In some other embodiments of the invention, only one or two protrusions 80a might be implemented to support the heating cartridge 30.

[0028] The protrusions 80a can be integral parts of the heating cartridge 30 in some embodiments of the invention. The protrusions 80a can be made by molding or machining the heating cartridge 30 into a profile having pointed contacts with the inner surface of the tube 28 via the protrusions 80a. In some other embodiments of the invention, the protrusions 80a can be made by attaching small objects to the outer surface of the heating cartridges 30.

[0029] FIG. 6 illustrates a cross-sectional view of supporting means 90 in accordance with some embodiments of the invention. In FIG. 6, the supporting means 90 is configured in the form of a spacer 90a inserted between the heating cartridge 30 and the inner wall of the tube 28. The spacer 90a has a number of openings 90b, which allow the exhaust gas to pass therethrough, such that the gas flow from the inlet 52 to the outlet 54 of the tube 28 is not blocked by the spacer 90a.

[0030] Although the invention is illustrated and described herein as embodied in one or more specific examples, it is nevertheless not intended to be limited to the details shown, since various modifications and structural changes may be made therein without departing from the spirit of the invention and within the scope and range of equivalents of the claims. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention, as set forth in the following claims.

WHAT IS CLAIMED IS:

1. A cartridge heater apparatus comprising:
a tube;
a heating cartridge adapted to be inserted into the tube for heating fluid passing through a passage space between the heating cartridge and the tube, the heating cartridge being secured at a first end thereof in a cantilever manner; and
means for supporting the heating cartridge in the tube at a location distant from the first end, without blocking the fluid passing through the passage space between the heating cartridge and the tube.
2. The cartridge heater apparatus of claim 1, wherein the means comprises at least one recessed portion on an inner wall of the tube in contact with the heating cartridge inserted in the tube.
3. The cartridge heater of apparatus of claim 2, wherein the means comprises at least three said recessed portions spread around the heating cartridge at the same location in an axial direction of the tube.
4. The cartridge heater apparatus of claim 1, wherein the means comprises at least one protrusion on a surface of the heating cartridge in contact with an inner wall of the tube.
5. The cartridge heater apparatus of claim 4, wherein the means comprises at least three said protrusions spread around the heating cartridge at the same location in an axial direction of the same.
6. The cartridge heater apparatus of claim 4, wherein the protrusion is an integral or separate part of the heating cartridge.
7. The cartridge heater apparatus of claim 1, wherein the means comprises a spacer adapted to be placed between an inner wall of the tube and the heating cartridge, the spacer having one or more openings for allowing the fluid to pass therethrough.
8. The cartridge heater apparatus of claim 1, wherein the tube has an inlet disposed between the first end and the means.

9. The cartridge heater apparatus of claim 1, wherein the heating cartridge has a cylinder-shaped body enclosing an electrical resistor adapted to be connected to a power supply.
10. The cartridge heater apparatus of claim 9 further comprising a thermal couple fluidly connected to the tube for generating a first signal indicative of a temperature of the fluid in the tube.
11. The cartridge heater apparatus of claim 10 further comprising a controller for controlling the power provided to the heating cartridge from the power supply in response to the first signal.
12. The cartridge heater apparatus of claim 9 further comprising an over-temperature protection switch attached onto an outer surface of the tube for generating a second signal indicative of a temperature of the tube.
13. The cartridge heater apparatus of claim 12 further comprising a controller for switching off the power provided to the heating cartridge from the power supply when the second signal exceeds a predetermined threshold value.
14. A system comprising:
a process chamber;
a vacuum pump arrangement connected to an outlet of the process chamber for evacuating fluid from the process chamber;
an abatement device connected to an outlet of the vacuum pump arrangement via a tube for treating exhaust fluid emitted from the vacuum pump arrangement;
a heating cartridge adapted to be inserted into the tube for heating the exhaust fluid passing through a passage space between the heating cartridge and the tube, the heating cartridge being secured at a first end thereof in a cantilever manner; and
means for supporting the heating cartridge in the tube at a location distant from the first end, without blocking the exhaust fluid passing through the passage space between the heating cartridge and the tube.
15. The system of claim 14, wherein the means comprises at least one recessed portion on an inner wall of the tube in contact with the heating cartridge inserted in the tube.

16. The system of claim 15, wherein the means comprises at least three said recessed portions spread around the heating cartridge at the same location in an axial direction of the tube.
17. The system of claim 14, wherein the means comprises at least one protrusion on a surface of the heating cartridge in contact with an inner wall of the tube.
18. The system of claim 17, wherein the means comprises at least three said protrusions spread around the heating cartridge at the same location in an axial direction of the same.
19. The system of claim 14, wherein the means comprises a spacer adapted to be placed between an inner wall of the tube and the heating cartridge, the spacer having one or more openings for allowing the exhaust fluid to pass therethrough.
20. The system of claim 14, wherein the tube has an inlet disposed between the first end and the means.
21. The system of claim 14, wherein the heating cartridge has a cylinder-shaped body enclosing an electrical resistor adapted to be connected to a power supply.
22. The system of claim 21 further comprising a thermal couple fluidly connected to the tube for generating a first signal indicative of a temperature of the exhaust fluid in the tube.
23. The system of claim 22 further comprising a controller for controlling the power provided to the heating cartridge from the power supply in response to the first signal.
24. The system of claim 21 further comprising an over-temperature protection switch attached onto an outer surface of the tube for generating a second signal indicative of a temperature of the tube.
25. The system of claim 24 further comprising a controller for switching off the power provided to the heating cartridge from the power supply when the second signal exceeds a predetermined threshold value.

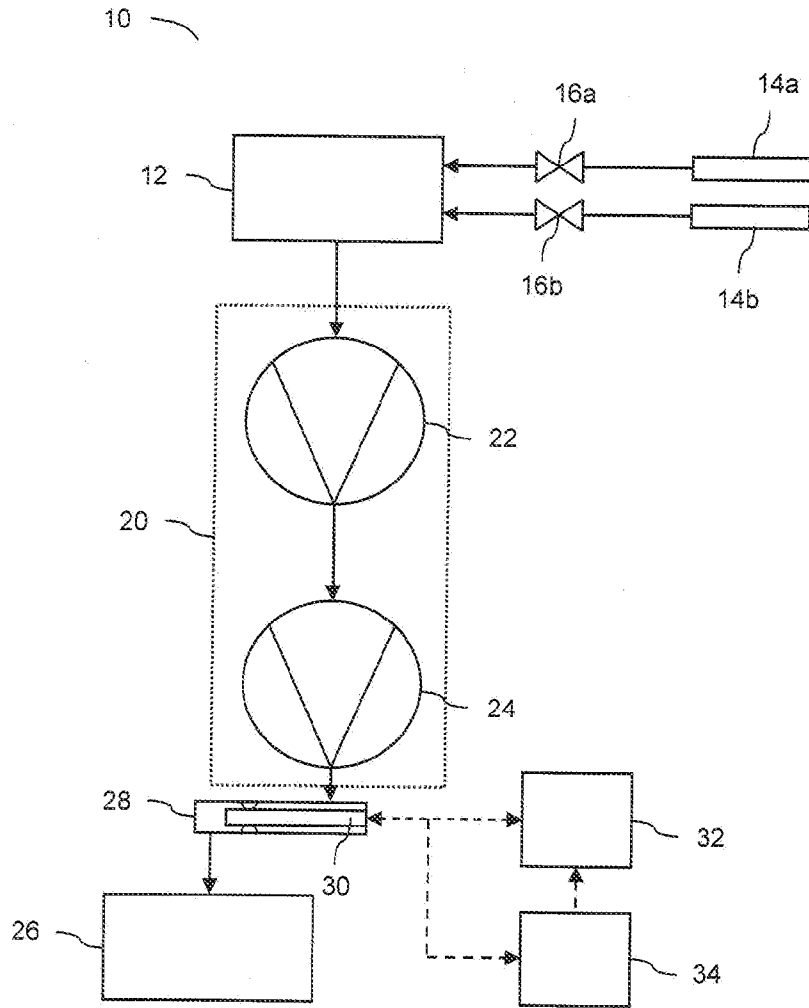


FIG. 1

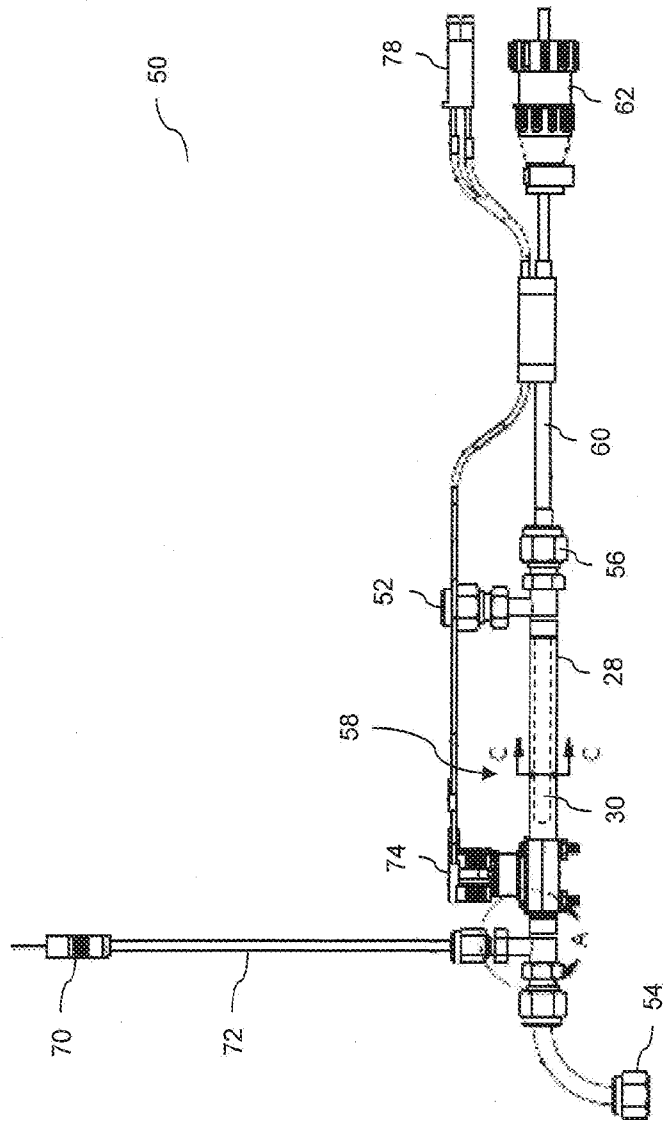


FIG. 2

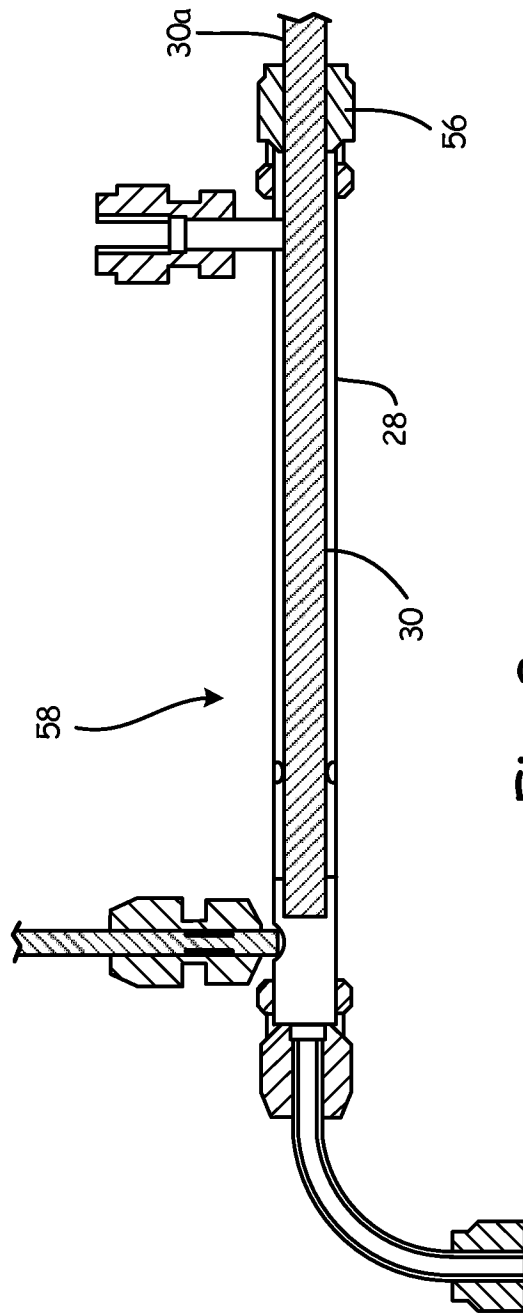


Fig. 3

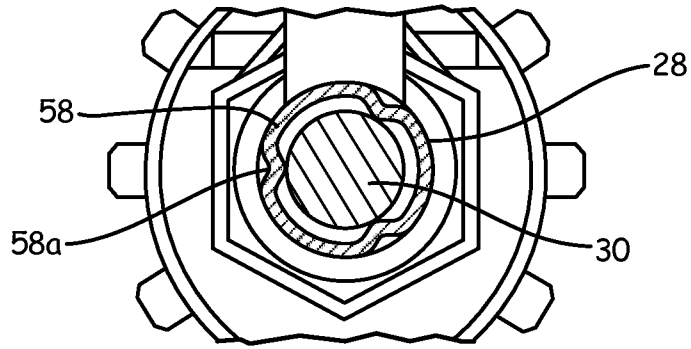


Fig. 4

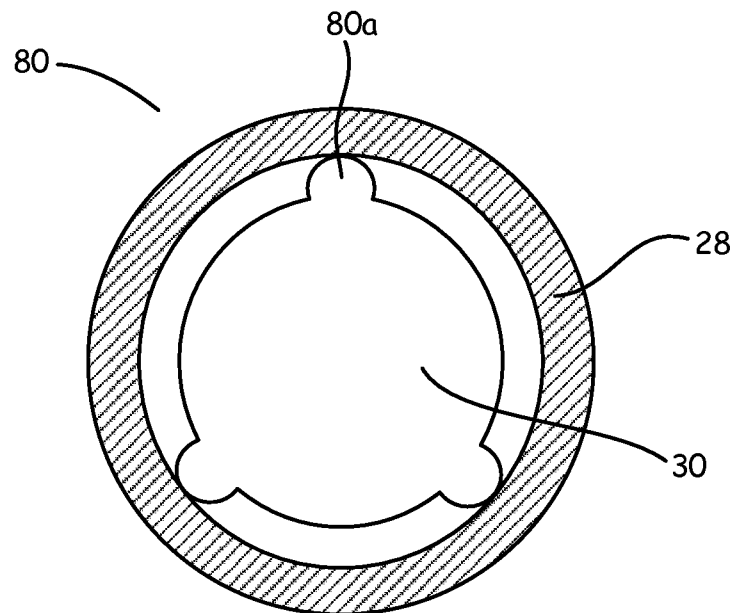


Fig. 5

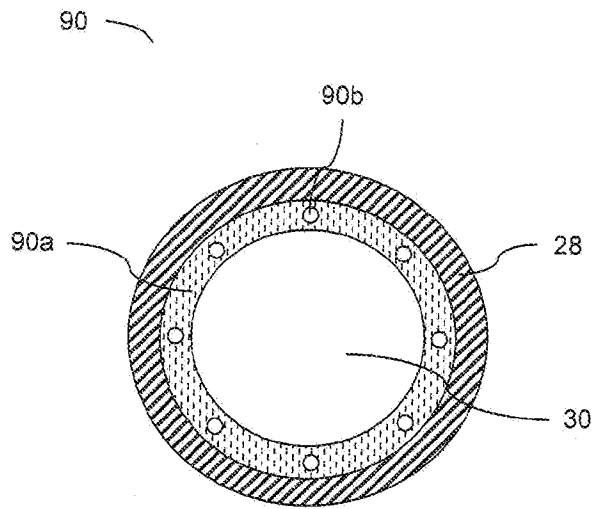


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 13/65196

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - H05B 3/40; H05B 3/78 (2014.01)

USPC - 385/13

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)
USPC: 385/13Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 219/201, 385, 429, 436, 437, 520, 523, 534, 536, 538, 542, 552; 422/33; 137/341, 565.23 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase; PubWEST; Google

Search Terms Used: cartridge, heater, heating, tube, process, chamber, abatement, cantilevered, flow, support, secure, mount, pipe, barrel, insert, tank, housing, resistor, recessed, porous, holes, spacer, temperature

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y -- A	DAVIS et al., Development and qualification of a vacuum pumping system for metal organic vapor phase epitaxy copper precursors, American Vacuum Society, 2000. [retrieved on 18 February 2014 (18.02.2014)]. Retrieved from the Internet:<URL: http://www.cantab.net/users/raul.abreu/documents/Page%203%20documents/Raul_Publication_s/14-Development_and_Qualification.pdf > pgs 2795-2796	1, 4-14, 17-25 ----- 2, 3, 15, 16
Y -- A	The Applicant's Admitted Prior Art, current application at paras [0002]-[0004]	1, 4-14, 17-25 ----- 2, 3, 15, 16
Y	US 6,707,370 B2 (Ritt et al.) 16 March 2004 (16.03.2004), especially Fig. 3-4 and col 2, ln 34-36, col 3, ln 5-10 and ln 49-61	12, 13, 24, 25
A	US 5,486,682 A (Rysemus) 23 January 1996 (23.01.1996), entire document	1-25
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A	US 2,015,641 A (Colbie) 24 September 1935 (24.09.1935), entire document	1-25

 Further documents are listed in the continuation of Box C.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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Date of the actual completion of the international search

19 February 2014 (19.02.2014)

Date of mailing of the international search report

13 MAR 2014

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