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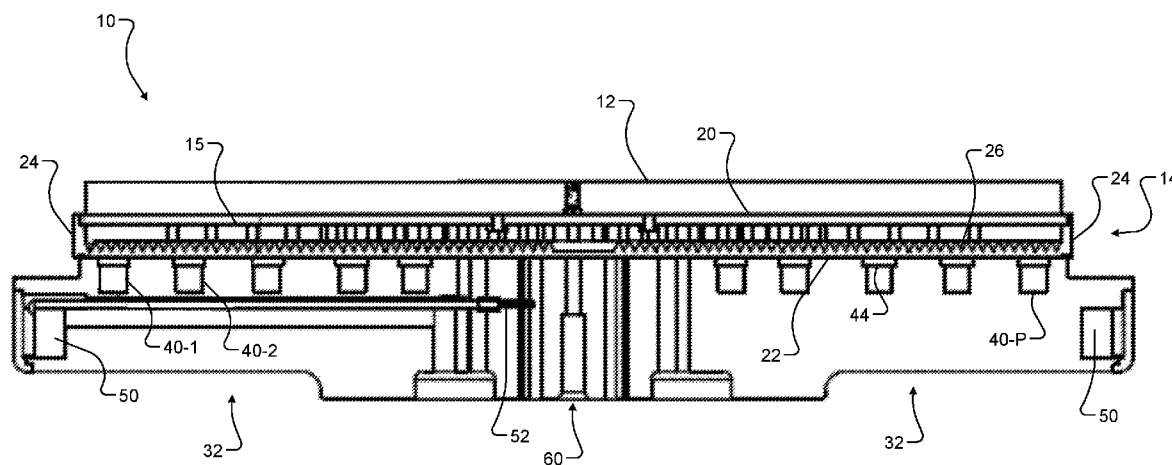
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(54) Title: PEDESTAL INCLUDING VAPOR CHAMBER FOR SUBSTRATE PROCESSING SYSTEMS

FIG. 2



(57) Abstract: A substrate support for a substrate processing system includes a pedestal including an upper surface and a lower surface. A vapor chamber is arranged between the pedestal and a baseplate, defines a vapor chamber cavity and includes a plurality of capillary structures arranged on a surface inside of the vapor chamber cavity.

PEDESTAL INCLUDING VAPOR CHAMBER FOR SUBSTRATE PROCESSING SYSTEMS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 62/772,364, filed on November 28, 2018. The entire disclosure of the application referenced above is incorporated herein by reference.

FIELD

[0002] The present disclosure relates to substrate processing systems, and more particularly to pedestal temperature control systems for substrate processing systems.

BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] Substrate processing systems typically include a processing chamber that includes a pedestal. A substrate such as a semiconductor wafer may be arranged on the pedestal. For example in chemical vapor deposition (CVD) processes, a gas mixture may be introduced into the processing chamber to deposit a film on the substrate or to etch the substrate. In some situations, plasma may be used. It may be desirable to control a temperature of the pedestal and the substrate during processing to improve uniformity of etching or deposition.

[0005] To improve temperature uniformity, some systems use multiple heaters that are embedded in different heating zones of the pedestal. For example, the heaters may be arranged at different radii of the pedestal. Thermocouples may be used to monitor the temperatures in the heating zones. A control system controls power to each heating zone to create temperature uniformity based on measured temperatures of the pedestal in the different zones. If sensing is not performed in real time, different types of processes may require different heater calibrations. The control system for the heaters

may be expensive and may introduce points of failure to the substrate processing system.

[0006] Despite the use of different heating zones, localized temperature differences may still occur. In an effort to further increase temperature uniformity, some systems have added as many as 30 heaters to achieve a high level of temperature uniformity, which increases cost and complexity. These systems may still not achieve the desired amount of temperature uniformity.

SUMMARY

[0007] A substrate support for a substrate processing system includes a pedestal including an upper surface and a lower surface. A vapor chamber is arranged between the pedestal and a baseplate, defines a vapor chamber cavity and includes a plurality of capillary structures arranged on a surface inside of the vapor chamber cavity.

[0008] In other features, the baseplate includes fluid passages in thermal communication with a lower surface of the vapor chamber. The fluid passages are arranged in a spiral pattern. A cover is arranged over the fluid passages adjacent to the lower surface of the vapor chamber. A working fluid is located in the vapor chamber, the plurality of capillary structures are arranged on a lower surface of the vapor chamber and further comprising a fluid supply configured to supply a fluid to the fluid passages having a higher temperature than the working fluid to cause the working fluid on the plurality of capillary structures to vaporize and condense on cooler surfaces in the vapor chamber cavity.

[0009] In other features, a working fluid is located in the vapor chamber, the plurality of capillary structures are arranged on an upper surface of the vapor chamber, and heat from the pedestal causes the working fluid on the plurality of capillary structures to vaporize and condense on cooler surfaces in the vapor chamber cavity. A fluid supply is configured to supply a fluid to the fluid passages having a lower temperature than the working fluid. The plurality of capillary structures is arranged on at least one of a lower surface, an upper surface and sidewalls of the vapor chamber cavity.

[0010] In other features, the vapor chamber performs heating and the plurality of capillary structures are arranged on a lower surface of the vapor chamber cavity.

[0011] In other features, the vapor chamber performs cooling and the plurality of capillary structures are arranged on an upper surface of the vapor chamber cavity. The

plurality of capillary structures move a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include fabric that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.

[0012] A vapor chamber for a substrate support of a substrate processing system includes a body including an upper surface, a lower surface and side walls defining a vapor chamber cavity. A plurality of capillary structures is arranged on at least one of an upper surface, a lower surface and side walls inside of the vapor chamber cavity. The vapor chamber is configured to be arranged between a pedestal and a baseplate of the substrate support.

[0013] In other features, a working fluid is located in the vapor chamber. The vapor chamber supplies heat to the pedestal. The plurality of capillary structures are arranged on a lower surface of the vapor chamber to vaporize the working fluid and condense the working fluid on cooler surfaces in the vapor chamber cavity.

[0014] In other features, a working fluid is located in the vapor chamber, the vapor chamber performs cooling of the pedestal, and the plurality of capillary structures are arranged on an upper surface of the vapor chamber to vaporize the working fluid and condense the working fluid on cooler surfaces in the vapor chamber cavity.

[0015] In other features, the plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include fabric that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.

[0016] A method for manufacturing a substrate support for a substrate processing system include defining a vapor chamber cavity in a vapor chamber body; arranging a plurality of capillary structures arranged on a surface inside of the vapor chamber cavity; and arranging the vapor chamber body between a pedestal and a baseplate.

[0017] In other features, the method includes defining fluid passages in the baseplate, wherein the fluid passages are in thermal communication with a lower surface of the vapor chamber body. The method includes arranging the fluid passages in a spiral pattern. The method includes arranging a cover over the fluid passages adjacent to the lower surface of the vapor chamber.

[0018] In other features, the method includes arranging the plurality of capillary structures on a lower surface of the vapor chamber; and supplying a working fluid in the vapor chamber body. The method includes arranging the plurality of capillary structures on an upper surface of the vapor chamber; and supplying a working fluid in the vapor chamber body.

[0019] In other features, the plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include fabric that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by capillary action. The plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.

[0020] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0022] FIG. 1 is a partial perspective view of a pedestal including a vapor chamber according to the present disclosure;

[0023] FIG. 2 is a cross-sectional view of a pedestal including a vapor chamber according to the present disclosure; and

[0024] FIG. 3 is a partial cross-sectional view of a pedestal including a vapor chamber according to the present disclosure.

[0025] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

[0026] According to the present disclosure, a temperature of a pedestal is controlled
5 using a vapor chamber that is arranged below the pedestal.

[0027] Referring now to FIGs. 1, 2 and 3, pedestal temperature control system 10 includes a pedestal 12 and a vapor chamber 14 arranged to control a temperature of the pedestal 12. In some examples, the pedestal 12 includes a ceramic base material having an outer surface that is plated. In some examples, the ceramic material
10 includes aluminum nitride (AlN), although other materials may be used. In some examples, the pedestal is an electrostatic chuck that uses electrostatic charge to hold the substrate in place during substrate processing, although mechanical or other types of chuck may be used.

[0028] In some examples, the vapor chamber 14 defines a vapor chamber cavity 15
15 that is in a form of a disk or flat cylindrical cavity. The vapor chamber cavity 15 of the vapor chamber 14 is defined by an upper surface 20, a lower surface 22, and side walls 24 arranged around an outer periphery of the flat cylindrical opening. A working fluid located in the vapor chamber 14 is used to provide heating or cooling within the vapor chamber 14 as needed to increase temperature uniformity.

[0029] An inwardly facing side of the lower surface 22 includes a plurality of capillary
20 structures 26. For example only, the capillary structures 26 may include a wicking material, fabric, a powdered material such as a metallic or nonmetallic powder, grooves or other structures that can move fluid by capillary action. In some examples, the metallic powder is sintered to an inner side of the lower surface 22 of the vapor
25 chamber 14. As can be appreciated, the capillary structures 26 may also be formed on an inner side of the upper surface 20 and/or an inner side of the side walls 24.

[0030] A base portion 32 may be arranged below the vapor chamber 14. In some examples, the base portion 32 may be made of aluminum. The base portion 32 may define fluid passages 40-1, 40-2 ..., and 40-P, where P is an integer (collectively fluid
30 passages 40). For example only, the fluid passages 40 may be arranged in a spiral pattern or any other suitable pattern. Water or another type of fluid may flow in the fluid passages 40 to provide heating or cooling. A top portion of the fluid passages 40 may

be enclosed by a cover 44. In some examples, the cover 44 is welded in place to seal the fluid passages 40.

[0031] A controller, one or more valves, one or more pumps, and thermocouples may be used to control a heated and/or cooled fluid source. For example in FIG. 1, a temperature-controlled fluid supply 60, a pump 64 and a valve 68 may be used to supply fluid at a predetermined temperature above or below the working fluid to the fluid passages 40.

[0032] One or more coils 50 may be provided to supply heat to the base portion 32. A connector 52 may be connected from a radially inner portion of the base portion 32 to the one or more coils 50 that are located adjacent to an outer circumference of the pedestal. Gas ("backside gas") may be supplied to a substrate resting on the pedestal 12 via passage 60. A lift pin assembly (not shown) may be used to lift the substrate from the pedestal 12.

[0033] In operation, the vapor chamber 14 encloses a working fluid. For example, another fluid that is hotter than the lower surface 22 of the vapor chamber 14 may be supplied by the heated fluid source to the fluid passages 40. The fluid in the fluid passages 40 supplies heat to the lower surface 22 of the vapor chamber 14. Working fluid located in the vapor chamber 14 on the lower surface 22 vaporizes. The vapor disburses uniformly inside the vapor chamber 14 and is condensed on cooler surfaces that are at a lower temperature. This action increases the temperature of these cooler surfaces. At the same time, working fluid on the capillary structures 26 replaces the working fluid that vaporizes. In this example, the heating action of the working fluid will tend to make all of the surfaces in the vapor chamber 14 have a more uniform temperature.

[0034] As can be appreciated, the vapor chamber 14 can also perform cooling. In this application, the capillary structures are arranged on the top surface of the vapor chamber instead of the bottom surface. For example, another fluid that is cooler than the lower surface 22 of the vapor chamber 14 may be supplied by a cooled fluid source to the fluid passages 40. The fluid in the fluid passages 40 cools the lower surface 22 of the vapor chamber 14. Working fluid located in the vapor chamber 14 on the lower surface 22 condenses and becomes liquid. The liquid is moved by capillary action to hotter surfaces inside the vapor chamber 14 and vaporizes on the hotter surfaces that are at a higher temperature. This action decreases the temperature of these hotter

surfaces. At the same time, working fluid on the capillary structure 26 replaces the working fluid that vaporizes. In this example, the cooling action of the working fluid will tend to make all of the surfaces in the vapor chamber 14 have a more uniform temperature.

- 5 **[0035]** According to the present disclosure, temperature uniformity on the surface of the pedestal is achieved by creating a very high thermal conductivity sealed vapor chamber beneath a surface of a pedestal 12 that conducts heat at a high rate. For example only, heat may be conducted at a rate of 8,000-20,000 Watts per meter Kelvin (W/mK). Note that aluminum conducts at ~ 200 W/mK.
- 10 **[0036]** In use, vapor carrying heat may automatically be deposited on lower temperature surfaces, or even portions of surfaces, within the vapor chamber, thereby creating a system that is passively and continuously seeking thermal uniformity. The working fluid (e.g., water, alcohol, or other fluid) can be varied so as to be suitable to the temperature range desired of the pedestal and/or the materials used in making the
- 15 vapor chamber. As a result, the need for many heating zones is reduced or eliminated.
- 20 **[0037]** The foregoing description is merely illustrative in nature and is in no way intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited
- 25 since other modifications will become apparent upon a study of the drawings, the specification, and the following claims. As used herein, the phrase at least one of A, B, and C should be construed to mean a logical (A or B or C), using a non-exclusive logical OR. It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure.

CLAIMS

What is claimed is:

1. A substrate support for a substrate processing system, comprising:
a pedestal including an upper surface and a lower surface;
5 a baseplate; and
a vapor chamber arranged between the pedestal and the baseplate, defining a vapor chamber cavity and including a plurality of capillary structures arranged on a surface inside of the vapor chamber cavity.
2. The substrate support of claim 1, wherein the baseplate includes fluid passages
10 in thermal communication with a lower surface of the vapor chamber.
3. The substrate support of claim 2, wherein the fluid passages are arranged in a spiral pattern.
4. The substrate support of claim 3, further comprising a cover arranged over the fluid passages adjacent to the lower surface of the vapor chamber.
- 15 5. The substrate support of claim 2, wherein a working fluid is located in the vapor chamber, the plurality of capillary structures are arranged on a lower surface of the vapor chamber and further comprising a fluid supply configured to supply a fluid to the fluid passages having a higher temperature than the working fluid to cause the working fluid on the plurality of capillary structures to vaporize and condense on cooler surfaces
20 in the vapor chamber cavity.
6. The substrate support of claim 2, wherein a working fluid is located in the vapor chamber, the plurality of capillary structures are arranged on an upper surface of the vapor chamber, and heat from the pedestal causes the working fluid on the plurality of capillary structures to vaporize and condense on cooler surfaces in the vapor chamber
25 cavity.
7. The substrate support of claim 6, further comprising a fluid supply configured to supply a fluid to the fluid passages having a lower temperature than the working fluid.

8. The substrate support of claim 1, wherein the plurality of capillary structures are arranged on at least one of a lower surface, an upper surface and sidewalls of the vapor chamber cavity.
9. The substrate support of claim 1, wherein the vapor chamber performs heating and the plurality of capillary structures are arranged on a lower surface of the vapor chamber cavity.
10. The substrate support of claim 1, wherein the vapor chamber performs cooling and the plurality of capillary structures are arranged on an upper surface of the vapor chamber cavity.
11. The substrate support of claim 1, wherein the plurality of capillary structures move a working fluid in the vapor chamber cavity by capillary action.
12. The substrate support of claim 1, wherein the plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action.
13. The substrate support of claim 1, wherein the plurality of capillary structures include fabric that moves a working fluid in the vapor chamber cavity by capillary action.
14. The substrate support of claim 1, wherein the plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by capillary action.
15. The substrate support of claim 1, wherein the plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.

16. A vapor chamber for a substrate support of a substrate processing system, comprising:

a body including an upper surface, a lower surface and side walls defining a vapor chamber cavity; and

5 a plurality of capillary structures arranged on at least one of an upper surface, a lower surface and side walls inside of the vapor chamber cavity,

wherein the vapor chamber is configured to be arranged between a pedestal and a baseplate of the substrate support.

17. The vapor chamber of claim 16, wherein:

10 a working fluid is located in the vapor chamber,

the vapor chamber supplies heat to the pedestal, and

the plurality of capillary structures are arranged on a lower surface of the vapor chamber to vaporize the working fluid and condense the working fluid on cooler surfaces in the vapor chamber cavity.

15 18. The vapor chamber of claim 16, wherein:

a working fluid is located in the vapor chamber,

the vapor chamber performs cooling of the pedestal, and

20 the plurality of capillary structures are arranged on an upper surface of the vapor chamber to vaporize the working fluid and condense the working fluid on cooler surfaces in the vapor chamber cavity.

19. The vapor chamber of claim 16, wherein the plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action.

20. The vapor chamber of claim 16, wherein the plurality of capillary structures
25 include fabric that moves a working fluid in the vapor chamber cavity by capillary action.

21. The vapor chamber of claim 16, wherein the plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by capillary action.

22. The vapor chamber of claim 16, wherein the plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.
23. A method for manufacturing a substrate support for a substrate processing system, comprising:
5 defining a vapor chamber cavity in a vapor chamber body;
arranging a plurality of capillary structures arranged on a surface inside of the vapor chamber cavity; and
arranging the vapor chamber body between a pedestal and a baseplate.
- 10 24. The method of claim 23, further comprising defining fluid passages in the baseplate, wherein the fluid passages are in thermal communication with a lower surface of the vapor chamber body.
25. The method of claim 24, further comprising arranging the fluid passages in a spiral pattern.
- 15 26. The method of claim 25, further comprising arranging a cover over the fluid passages adjacent to the lower surface of the vapor chamber.
27. The method of claim 24, further comprising:
arranging the plurality of capillary structures on a lower surface of the vapor chamber; and
20 supplying a working fluid in the vapor chamber body.
28. The method of claim 24, further comprising:
arranging the plurality of capillary structures on an upper surface of the vapor chamber; and
supplying a working fluid in the vapor chamber body.
- 25 29. The method of claim 23, wherein the plurality of capillary structures include a wicking material that moves a working fluid in the vapor chamber cavity by capillary action.

30. The method of claim 23, wherein the plurality of capillary structures include fabric that moves a working fluid in the vapor chamber cavity by capillary action.

31. The method of claim 23, wherein the plurality of capillary structures include a sintered powdered material that moves a working fluid in the vapor chamber cavity by
5 capillary action.

32. The substrate support of claim 23, wherein the plurality of capillary structures include a grooved material that moves a working fluid in the vapor chamber cavity by capillary action.

FIG. 1

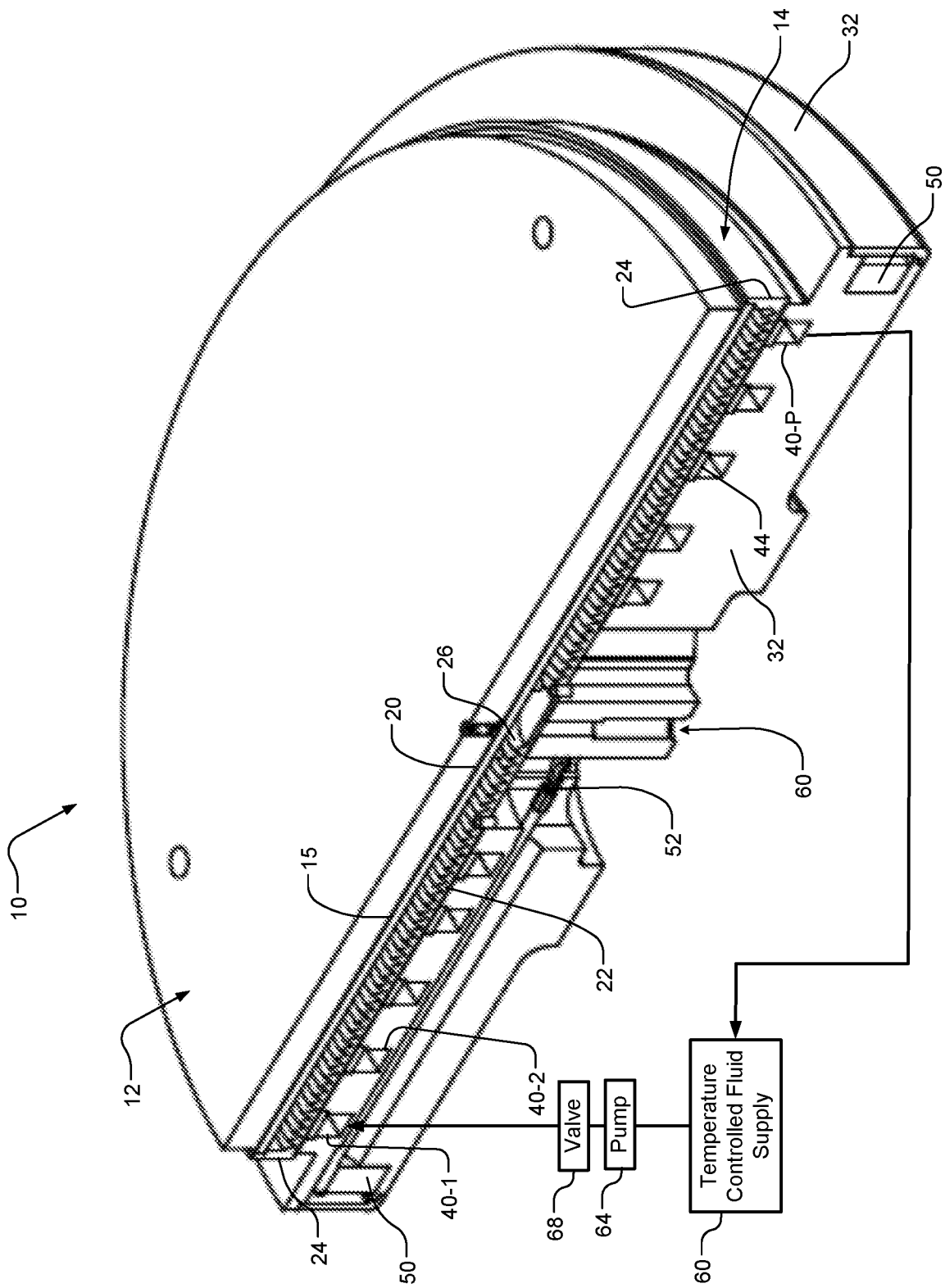


FIG. 2

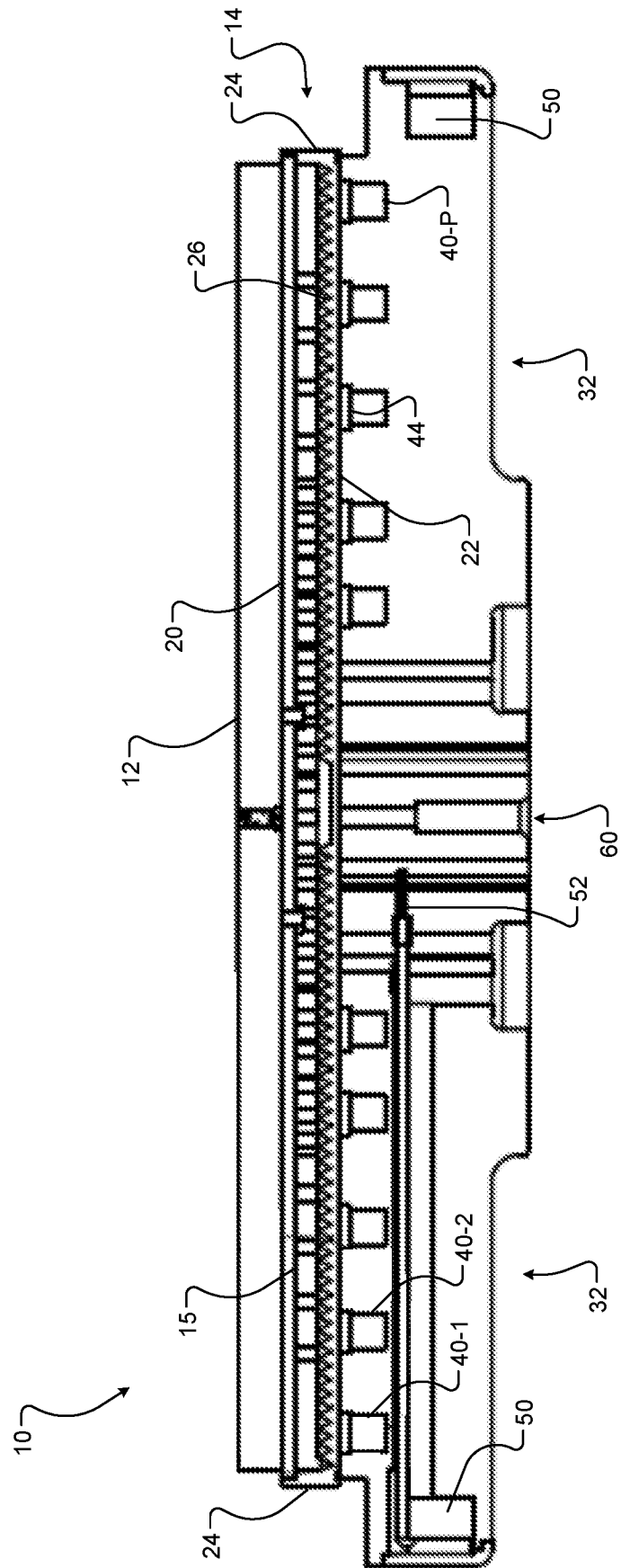
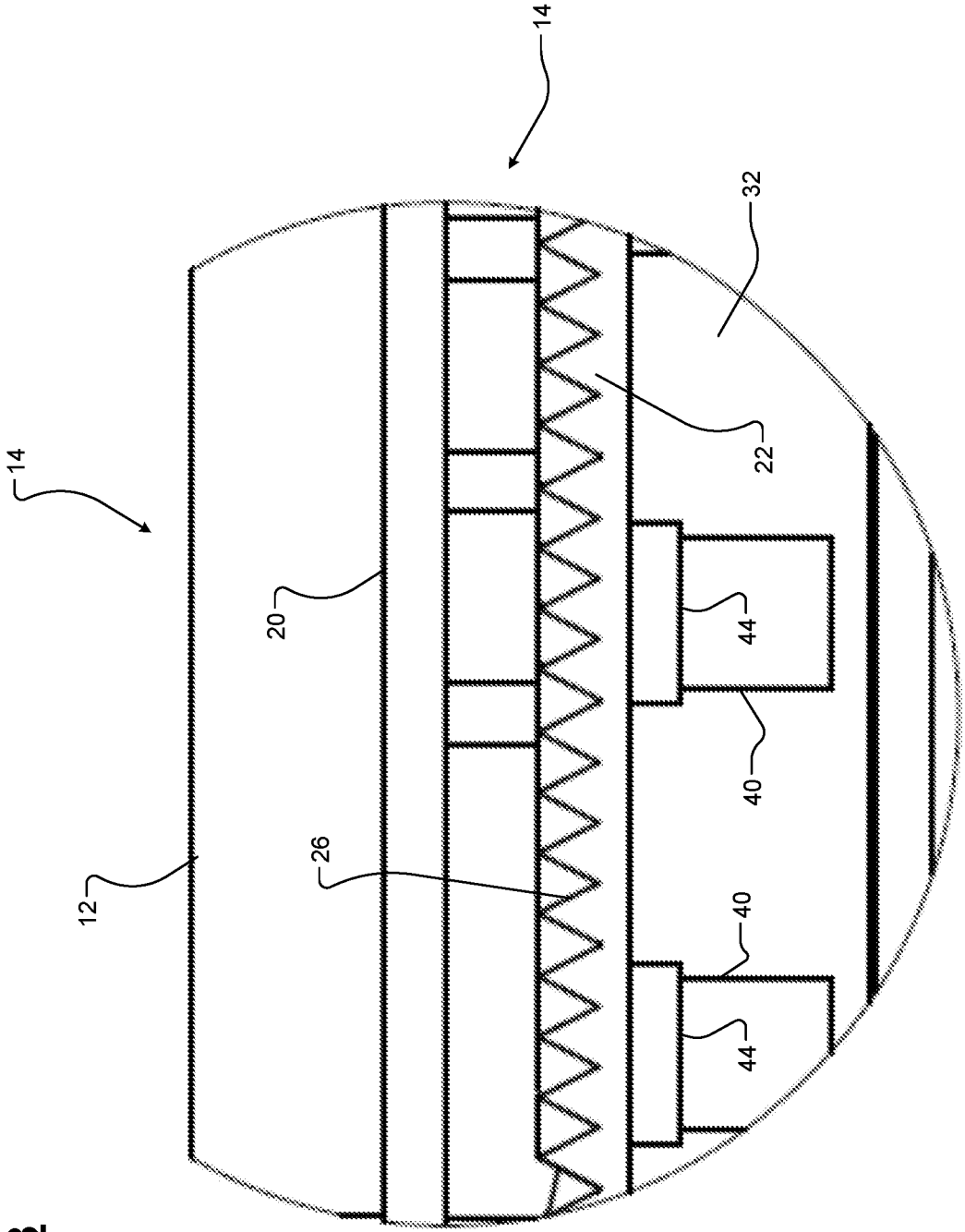


FIG. 3



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2019/063238**A. CLASSIFICATION OF SUBJECT MATTER****C23C 16/458(2006.01)i, C23C 16/46(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)

C23C 16/458; B01D 53/26; F25B 21/04; G05D 23/20; H01J 37/32; H01L 21/027; H01L 21/68; H05K 7/20; C23C 16/46

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: temperature, control, pedestal, vapor chamber, baseplate, capillary structure

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2017-0110298 A1 (LAM RESEARCH CORPORATION) 20 April 2017 paragraphs [0020]–[0029], [0040]–[0041], claim 1, and figure 1	1–32
Y	JP 05-021308 A (CANON INC.) 29 January 1993 paragraphs [0026], [0042] and figures 2, 4	1–32
Y	US 2006-0207750 A1 (CHANG et al.) 21 September 2006 paragraph [0023] and claims 1–2	13–15, 20–22, 30–32
A	JP 2007-257014 A (YAMAHA CORP.) 04 October 2007 paragraphs [0024]–[0029] and claim 1	1–32
A	CN 105722372 A (ASIA VITAL COMPONENTS CO., LTD.) 29 June 2016 claims 1–10 and figures 1–3	1–32



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2019/063238

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