



(51) International Patent Classification:
C23C 16/455 (2006.01)

(21) International Application Number:
PCT/US2020/020070

(22) International Filing Date:
27 February 2020 (27.02.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/824,369 27 March 2019 (27.03.2019) US

(71) Applicant: **APPLIED MATERIALS, INC.** [US/US];
3050 BOWERS AVENUE, SANTA CLARA, California
95054 (US).

(72) Inventors: **AGARWAL, Sumit**; c/o Applied Materials,
Inc., Law Dept., M/S 1269, 3050 Bowers Avenue, Santa
Clara, California 95054 (US). **BALUJA, Sanjeev**; c/o Ap-
plied Materials, Inc., Law Dept., M/S 1269, 3050 Bowers
Avenue, Santa Clara, California 95054 (US). **PETERSON,**

Chad; c/o Applied Materials, Inc., Law Dept., M/S 1269,
3050 Bowers Avenue, Santa Clara, California 95054 (US).

RICE, Michael R.; c/o Applied Materials, Inc., Law Dept.,
M/S 1269, 3050 Bowers Avenue, Santa Clara, California
95054 (US).

(74) Agent: **PATTERSON, B. Todd** et al.; PATTERSON +
SHERIDAN LLP, 24 Greenway Plaza, Suite 1600, Hous-
ton, Texas 77046 (US).

(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, DJ, DK, DM, DO,
DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN,
HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP,
KR, KW, KZ, LA, LC, LK, LR, LS, 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, ST, SV, SY, TH, TJ, TM, TN, TR,
TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(54) Title: GAS DISTRIBUTION PLATE WITH HIGH ASPECT RATIO HOLES AND A HIGH HOLE DENSITY

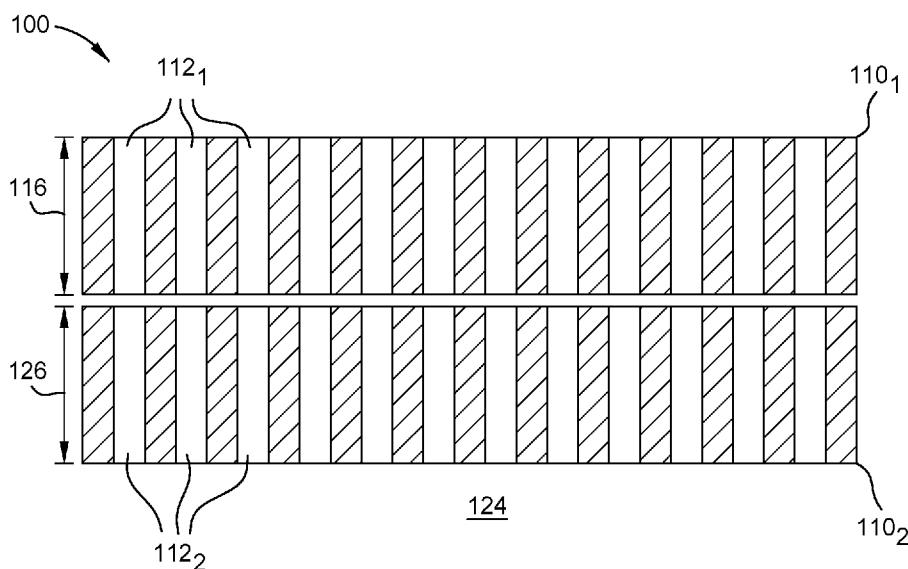


FIG. 1

(57) Abstract: A gas distribution plate for a showerhead assembly of a processing chamber may include at least a first plate and second plate. The first plate may include a first plurality holes each having a diameter of at least about 100 μ m. The second plate may include a second plurality of holes each having a diameter of at least about 100 μ m. Further, each of the first plurality of holes is aligned with a respective one of the second plurality of holes forming a plurality of interconnected holes. Each of the interconnected holes is isolated from each other interconnected holes.



(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, ST, 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))*

GAS DISTRIBUTION PLATE WITH HIGH ASPECT RATIO HOLES AND A HIGH HOLE DENSITY

BACKGROUND

[0001] Embodiments of the present disclosure generally relate to a showerhead for processing chambers, and, more particularly, to a showerhead having a high aspect ratio of holes and a high hole density for processing chambers.

Description of the Related Art

[0002] In many conventional showerhead designs, the showerhead includes a gas distribution plate having a plurality of holes through which a processing gas may flow. However, the number of holes and the aspect ratio of those holes may be limited. Hence, the uniformity of the flow of the processing gas through the showerhead is limited. A major factor in limiting the number of holes within a gas distribution plate is the process in which the holes are generated. For example, mechanical drilling of holes may place high levels of stress on the gas distribution plate potentially damaging the gas distribution plate and/or may create burrs within the gas distribution plate. Further, mechanical drilling is time prohibitive and may be process limited. For example, in many instances, mechanical drilling utilizes a spindle coolant fed drills, which are available in the smallest diameter size of about 500um, limiting the smallest possible hole that may be drilled. Other subtractive drilling methods include ultrasonic drilling or micro electrical discharge machining (EDM), which are both time prohibitive. A further example of subtractive drilling includes laser drilling which is typically limited to about a 10:1 aspect ratio and which is also time prohibitive. Accordingly, the conventional methods of generating holes limit the size of the holes and the aspect ratio of the holes, while increasing the manufacturing cost of the gas distribution plate. Further, the conventional methods of holes generation limit the hole density, which limits the uniformity of a process gas flowing through the gas distribution plate.

[0003] Therefore, in order to improve the uniformity of gas distribution, there is a need for improved fabrication methods to create a large number of small diameter holes in a gas distribution plate in a cost-effective way.

SUMMARY

[0004] In one embodiment, a gas distribution plate for a showerhead assembly includes a first plate and second plate. The first plate may comprise a first plurality of holes each having a diameter of at least about 100 μm . The second plate may comprise a second plurality of holes each having a diameter of at least about 100 μm . Further, each of the first plurality of holes is aligned with a respective one of the second plurality of holes forming a plurality of interconnected holes. Each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes.

[0005] In one embodiment, a method for forming a showerhead comprises generating a first plurality of holes in a first plate and generating a second plurality of holes in a second plate. Each of the first plurality of holes has a diameter of at least about 100 μm and each of the second plurality of holes has a diameter of about 100 μm . The method further comprises aligning each of the first plurality of holes with a respective one of the second plurality of holes to generate a plurality of interconnected holes, and bonding the first plate to the second plate. Each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes.

[0006] In one embodiment, a processing chamber comprises a showerhead assembly, a substrate support configured to support a substrate and a gas supply fluidly coupled with the showerhead assembly and configured to provide a process gas to the showerhead assembly. The showerhead assembly comprises a gas distribution plate including a first plate and second plate. The first plate comprises a first plurality of holes each having a diameter of at least about 100 μm . The second plate comprises a second plurality of holes each having a diameter of at least about 100 μm . Further, each of the first plurality of holes is aligned with a respective one of the second plurality of holes forming a plurality of interconnected holes, and each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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 exemplary embodiments and are therefore not to be considered limiting of scope, as the disclosure may admit to other equally effective embodiments.

[0008] Figures 1 and 2A are schematic cross-sectional view of a gas distribution plate, according to one or more embodiments.

[0009] Figure 2B is a schematic side view of a portion of a gas distribution plate, according to one or more embodiments.

[0010] Figure 3 is a schematic cross-sectional view of gas distribution plate, according to one or more embodiments.

[0011] Figures 4A, 4B, 4C, 4D, 4E, 4F, 4G, 4H, and 4I are schematic cross-sectional view of a gas distribution plate, according to one or more embodiments.

[0012] Figure 5 illustrates a flow chart of a method for forming a gas distribution plate, according to one or more embodiments.

[0013] Figure 6 is a schematic side view of a process chamber, according to one or more embodiments.

[0014] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0015] Embodiments for the present application include a gas distribution plate having high aspect ratio holes for a showerhead assembly. The gas distribution plate includes a plurality of holes through which a processing gas may flow. In many instances, by decreasing the size of each of the plurality of holes and by increasing the number of the plurality of holes, the uniformity of the process gas which is applied to a

substrate during processing may also be improved. Accordingly, embodiments of the following disclosure describe a gas distribution plate having a high number of small holes and a method for generating such a gas distribution plate while maintaining sufficient thickness of the gas distribution plate for adequate strength.

[0016] Figure 1 illustrates a gas distribution plate 100, according to one or more embodiments. The gas distribution plate 100 includes a plate 110₁ and a plate 110₂. The plate 110₁ may be connected to the plate 110₂ forming the gas distribution plate 100. Further, the gas distribution plate 100 may be part of a showerhead assembly, e.g., the showerhead assembly 616 of Figure 6.

[0017] The plate 110₁ comprises holes 112₁. Further, the plate 110₁ may be formed of aluminum, an aluminum alloy, molybdenum, a molybdenum alloy, nickel, a nickel alloy, or silicon, among others. The number of holes 112₁ may be about 50,000 or greater. Further, the number of holes 112₁ may be about 100,000 or greater. The diameter of each hole 112₁ may be at least about 100 μm . Further, the diameter of each hole 112₁ may be about 100 μm to about 600 μm . Alternatively, the diameter of each hole 112₁ may be less than about 100 μm or greater than about 600 μm . Further, each hole 112₁ may be of a common size (e.g., a common diameter). Alternatively, the diameter of one or more holes 112₁ differs from the diameter of another one of the holes 112₁.

[0018] Each of the holes 112₁ may have a uniform diameter. For example, the aspect ratio of each of the holes 112₁ may be substantially constant such that the diameter at any point within each hole 112₁ is the same, or within a manufacturing tolerance, as the diameter at any other point within each hole 112₁. Further, the size of each hole 112₁ at a first side of the plate 110₁ is the same, or within a manufacturing tolerance, as the size of each hole 112₁ at a second side of the plate 110₁. Alternatively, as will be described in greater detail with regard to the embodiment of Figures 4C, the diameter of a hole on a first side of the plate 110₁ may differ from the diameter of the hole on a second side of the plate 110₁.

[0019] The thickness 116 of the plate 110₁ may be in a range of about 200 um to about 900 um. Alternatively, the thickness 116 of the plate 110₁ may be less than about 200 um or greater than about 900 um.

[0020] The plate 110₂ includes holes 112₂. The plate 110₂ may be formed of aluminum, an aluminum alloy, molybdenum, a molybdenum alloy, nickel, a nickel alloy, or silicon, among others. Further, the plate 110₂ may be formed of the same material as plate 110₁ or a different material from plate 110₁. The number of holes 112₂ may be about 50,000 or greater. Further, the number of holes 112₂ may be about 100,000 or greater. The number of holes 112₂ may be the same as the number of holes 112₁. The diameter of each hole 112₂ may be about 100 um to about 600 um. Alternatively, the diameter of each hole 112₂ may be less than about 100 um or greater than about 600 um. Further, each hole 112₂ may be of a common size (e.g., a common diameter). Alternatively, the diameter of one or more holes 112₂ differs from the diameter of another one of the holes 112₂. Additionally, the diameter of each of the holes 112₂ may be the same as the diameter of each of the holes 112₁, or one or more holes 112₂ differs from the diameter of one or more of the holes 112₁.

[0021] Each of the holes 112₂ may have a uniform diameter. For example, the aspect ratio of each of the holes 112₂ may be substantially constant such that the diameter at any point of within each hole 112₂ is the same, or within a manufacturing tolerance, as the diameter at any other point within each hole 112₂. Further, the size of each hole 112₂ at a first side of the plate 110₂ is the same, or within a manufacturing tolerance, as the size of each hole 112₁ at a second side of the plate 110₂. Alternatively, as will be described in greater detail with regard to at least the embodiment of Figure 4C, the diameter of a hole on a first side of the plate 110₁ may differ from the diameter of the hole on a second side of the plate 110₁.

[0022] The thickness 126 of the plate 110₂ may be in a range of about 200 um to about 900 um. Alternatively, the thickness 126 of the plate 110₂ may be less than about 200 um or greater than about 900 um.

[0023] The gas distribution plate 100 and the plates 110₁, 110₂ may have a circular shape. For example, the gas distribution plate 100 may have a circular shape with a diameter in a range of about 200 mm to about 350 mm. Alternatively, the gas distribution plate 100 may have a diameter of less than about 200 mm or greater than about 350 mm. Further, the gas distribution plate 100 may have other shapes than a circular shape. For example, the gas distribution plate 100 may have an elliptical shape or a rectangular shape, among others. Further, while the gas distribution plate 100 is shown as including 2 plates, e.g., plate 110₁ and plate 110₂, the gas distribution plate 100 may include more than 2 plates. For example, as is illustrated in Figure 3, the gas distribution plate 100 may include 110_N plates, where N is greater than 2. Further, the total thickness of the gas distribution plate 100 may be about 25.4 mm. Alternatively, the total thickness of the gas distribution plate 100 may be less than about 25.4 mm or greater than about 25.4 mm.

[0024] The plates 110₁, 110₂ may be joined together to form the gas distribution plate 100. For example, as is illustrated in Figure 2A, the plates 110₁, 110₂ may be joined together, forming the gas distribution plate 100 and a plurality of interconnected holes 212.

[0025] Figure 2A illustrates the gas distribution plate 100, according to an embodiment. The gas distribution plate 100 of Figure 2A includes a combined plate 210 that is formed by joining or coupling the plates 110₁, 110₂ together such that each of the holes 112₁ is aligned with a respective one of the holes 112₂. Aligning each of the holes 112₁ with respective ones the holes 112₂ forms a plurality of interconnected holes 212. Each of the interconnected holes 212 is formed from one of the holes 112₁ and one of the fholes 112₂. Further, each of the interconnected holes 212 may be isolated from each other interconnected hole. For example, a processing gas may flow through each of the interconnected holes 212 but not between the interconnected holes 212. Further, each of the interconnected holes 212 may be same shape and/or size.

[0026] The combined plate 210 may be formed from a number of plates greater than 2. For example, the combined plate 210 may be formed from of at least N plates, where

N is 3 or more. The combined plate 210 may be formed from at least 10 plates. Further, the combined plate 210 may be formed from at least 100 plates.

[0027] Figure 2B illustrates a portion of a combined plate 210, according to one or more embodiments. The interconnected hole 212a has a diameter 214 and a height 216. Further, an aspect ratio of the interconnected hole 212 may be based on a ratio of the height 216 to the diameter 214. For example, the interconnected hole 212a may have an aspect ratio of at least about 50 to 1. Alternatively, the interconnected hole 212a may have an aspect ratio of less than about 50 to 1 or greater than about 50 to 1. Further, each of interconnected holes 212 may have about the same aspect ratio. Alternatively, the interconnected hole 212a may have an aspect ratio of about 25 to 1.

[0028] The diameter of each of the interconnected holes 212 may be substantially uniform. For example, at any point of an interconnected hole the diameter is the same, or within a manufacturing tolerance, of any other point of the interconnected hole. Stated another way, the aspect ratio of each interconnected holes is uniform or substantially similar (e.g., within a manufacturing tolerance) throughout the entirety of each interconnected hole. Further, the diameter of each interconnected hole 212 at a first side (e.g., surface) of the combined plate 210 is the same as the diameter of each interconnected hole 212 at a second side (e.g., surface) of the combined plate 210.

[0029] Figure 3 illustrates the gas distribution plate 100, according to one or more embodiments. The gas distribution plate 100 of Figure 3 includes the combined plate 300 formed by joining the plate 110₁, the plate 110₂, and a plate 110_N, where N is greater than 2. Further, the holes 112₁ of the plate 110₁, the holes 112₂ of the plate 110₂, and the holes 112_N of the plate 110_N are aligned to generate a plurality of interconnected holes.

[0030] Figure 4A illustrates plates 410₁ and 410₂ of a gas distribution plate 400a, according to one or more embodiments. While two plates are illustrated in the embodiment of Figure 4A, alternatively, the gas distribution plate 400b may include three or more plates. Further, the plate 410₁ may be bonded to the plate 410₂ forming

the gas distribution plate 400a. Additionally, the gas distribution plate 400a may be part of a showerhead assembly, e.g., the showerhead assembly 616 of Figure 6.

[0031] The plate 410₁ includes holes 412₁ and may be formed similar to that of plate 110₁ and 110₂. Further, the plate 410₂ includes holes 412₂ and may be formed similar to that of plate 110₁ and 110₂.

[0032] The diameter of each of the holes 412₂ may differ from the diameter from the diameter of each of the holes 412₁. For example, the diameter of the holes 412₁ along surface 424 of the plate 410₁ is larger than the diameter of the holes 412₂ along the surface 426 of the plate 410₂. Further, the diameter of the holes 412₂ along the surface 426 may be the same or may differ from the diameter of the holes 412₂ along the surface 428. For example, the diameter of the holes 412₂ along the surface 426 may be larger or smaller than the diameter of the holes 412₂ along the surface 428.

[0033] Utilizing plates having holes with different diameters may aid in the alignment of the plates before bonding to the plates together. For example, utilizing holes of different diameter allow for slight offsets in alignment of the holes while maintaining a similar cross section area for the gas flow as compared to utilizing holes of a common diameter which are fully aligned with each other.

[0034] Figure 4B illustrates a portion of gas distribution plate 400a, according to one or more embodiments. In particular, Figure 4B illustrates an interconnected hole 440a of gas distribution plate 400a formed after bonding the plate 410₁ with the plate 410₂. For example, the interconnected hole 440a is formed by joining the plate 410₁ with the plate 410₂, and comprises one of holes 412₁ and one of holes 412₂. Further, the diameter of interconnected hole 440 is non-uniform (i.e., a non-uniform diameter). For example, the diameter of the interconnected hole 440a along the surface 422 differs from the diameter of the interconnected hole 440 along the side 428. As illustrated in Figure 4B, the diameter of the interconnected hole 440a along the surface 422 is larger than the diameter of the interconnected hole 440a along the surface 428. Alternatively, the diameter of the interconnected hole 440a along the surface 422 may be smaller than the diameter of the interconnected hole 440a along the surface 428.

[0035] Figure 4C illustrates plates 410₃ and 410₄ of a gas distribution plate 400b, according to one or more embodiments. While two plates are illustrated in the embodiment of Figure 4C, alternatively, the gas distribution plate 400b may include three or more plates. Further, the plate 410₃ may be bonded to the plate 410₄ forming the gas distribution plate 400b. Additionally, the gas distribution plate 400b may be part of a showerhead assembly, e.g., the showerhead assembly 616 of Figure 6.

[0036] The plate 410₃ includes holes 412₃ and may be formed similar to that of plate 110₁ and 110₂. The plate 410₄ includes holes 412₄ and may be formed similar to that of plate 110₁ and 110₂.

[0037] Similar to that of plates 410₁ and 410₂, the diameter of each of the holes 412₃ may differ from the diameter of each of the holes 412₄. However, the holes 412₃ and/or the holes 412₄ may include a tapered region. For example, the holes 412₄ include a tapered region 434. Accordingly, the diameter of the holes 412₄ is non-uniform. For example, the diameter of the holes 412₄ along the surface 426 is larger than the diameter of the holes 412₄ along surface 428. Additionally, or alternatively, the diameter of the holes 412₃ may be non-uniform. For example, the diameter of the holes 412₃ along one of the surfaces 422 and 424 may differ from the diameter of the holes 412₃ along the other one of the surfaces 422 and 424. Further, the holes 412₃ may include a tapered region.

[0038] Figure 4D illustrates a portion of gas distribution plate 400b, according to one or more embodiments. In particular, Figure 4D illustrates an interconnected hole 440b of gas distribution plate 400b formed after bonding the plate 410₃ with the plate 410₄. For example, the interconnected hole 440a is formed by joining the plate 410₃ with the plate 410₄, and comprises one of holes 412₃ and one of holes 412₄. Accordingly, the diameter of interconnected hole 440b is non-uniform, differing between surface 422 and surface 428, and the interconnected hole 440b includes a tapered region 434. The diameter of the interconnected hole 440b along surface 422 may be larger or smaller than the diameter of the interconnected hole 440b along surface 428.

[0039] Figure 4E illustrates an interconnected hole 440c, according to one or more embodiments. The interconnected hole 440c may be formed from holes in two or more plates as illustrated in the embodiments of Figures 1, 3, 4A and/or 4C and described in the corresponding description. As illustrated in Figure 4E, the interconnected hole 440c includes a tapered region 444 disposed along the surface 422. Further, the diameter of the interconnected hole 440c is non-uniform, varying between the surface 422 and 428.

[0040] Figure 4F illustrates an interconnected hole 440d, according to one or more embodiments. The interconnected hole 440d may be formed from holes in two or more plates as illustrated in the embodiments of Figures 1, 3, 4A and/or 4C and described in the corresponding description. As illustrated in Figure 4F, the interconnected hole 440d includes a tapered region 454 disposed along the surface 422 and tapered region 456 disposed between the surface 422 and 428. Further, the diameter of the interconnected hole 440d is non-uniform, varying between the surface 422 and 428.

[0041] Figure 4G illustrates an interconnected hole 440e, according to one or more embodiments. The interconnected hole 440e may be formed from holes in two or more plates as illustrated in the embodiments of Figures 1, 3, 4A and/or 4C and described in the corresponding description. As illustrated in Figure 4G, the interconnected hole 440e includes a tapered regions 464 disposed along the surface 422 and tapered region 466 disposed along the surface 428. Further, the diameter of the interconnected hole 440e is non-uniform, varying between the surface 422 and 428. The diameter of the interconnected hole 440e along the surface 422 may be similar to (e.g., within a manufacturing tolerance) the diameter of the interconnected hole 440e along surface 428. Alternatively, the diameter of the interconnected hole 440e along the surface 422 differs from the diameter of the interconnected hole 440e along surface 428. For example, the diameter of the interconnected hole 440e along the surface 422 is greater than or less than the diameter of the interconnected hole 440e along surface 428.

[0042] Figure 4H illustrates an interconnected hole 440f, according to one or more embodiments. The interconnected hole 440f may be formed from holes in two or more plates as illustrated in the embodiments of Figures 1, 3, 4A and/or 4C and described in

the corresponding description. As illustrated in Figure 4H, the interconnected hole 440f includes a tapered region 474 disposed along the surface 428. Further, the diameter of the interconnected hole 440f is non-uniform, varying between the surface 422 and 428.

[0043] Figure 4I illustrates an interconnected hole 440e, according to one or more embodiments. The interconnected hole 440g may be formed from holes in two or more plates as illustrated in the embodiments of Figures 1, 3, 4A and/or 4C and described in the corresponding description. As illustrated in Figure 4I, the interconnected hole 440g includes a tapered region 484 disposed along the surface 422 and tapered region 486 disposed along the surface 428. Further, the diameter of the interconnected hole 440g is non-uniform, varying between the surface 422 and 428. In one or more embodiments, the diameter of the interconnected hole 440g along the surface 422 is greater than the diameter of the interconnected hole 440g along surface 428. Alternatively, the diameter of the interconnected hole 440g along the surface 428 may be greater than the diameter of the interconnected hole 440g along surface 422.

[0044] The plates 110₁, 110₂, 110_N may be bonded using any method suitable for bonding the plates without damaging the plates and while maintaining an independence between the interconnected holes. For example, Figure 5 illustrates a flowchart of a method for bonding plates to generate a gas distribution plate 100, according to one or more embodiments. At operation 510, a plurality of holes is generated in a first plate. For example, as is shown in Figure 1, the holes 112₁ are generated in plate 110₁. The holes 112₁ may be generated through a process of mechanical drilling, ultrasonic drilling, laser drilling, electro-discharge machining, or any other subtractive fabrication method.

[0045] At operation 520, a plurality of holes is generated in a second plate. For example, as is shown in Figure 1, the holes 112₂ are generated in the plate 110₂. The holes 112₁ may be generated through a process of mechanical drilling, ultrasonic drilling, laser drilling, electro-discharge machining, or any other subtractive fabrication method. Further, a similar method may be used to generate holes in any number of plates.

[0046] At operation 530, the plates are prepared for bonding. For example, the surfaces of plates 110 and 410 may be prepared for bonding to ensure that the surfaces are flat and clean to facilitate proper bonding of the plates. Preparing the surfaces for bonding may include one or more of polishing the surfaces, lapping the surfaces, cleaning the surfaces, and etching the surfaces, among others.

[0047] At operation 540, each of the plurality holes of the first plate is aligned with a respective one of the plurality of holes of the second plate. For example each of the holes 112₁ may be aligned with a respective one of the holes 112₂ forming a plurality of interconnected holes 212. Further, in embodiments where more than two plates are utilized to form a combined plate, the holes from any two plates may be aligned to form a plurality interconnected holes. Each of the interconnected holes may be formed from a hole from each of the plates utilized to form the gas distribution plate 100.

[0048] At operation 550, the first plate is bonded with the second plate. For example, the plates may be together using a brazing method (i.e., brazing technique), or a diffusion bonding method (i.e., a diffusion bonding technique), among others.

[0049] In a brazing method, the holes are aligned, the plates are stacked and a braze, or filler, sheet may be disposed and sandwiched between the plates. For example, the plate 110₁ may be stacked with plate 110₂ and each of the holes 112₁ may be aligned with a respective one of the holes 112₂. Additionally, after the braze sheets are placed on a plate and before the plates are stacked, the portions of the braze sheets that may be overlapping a hole in the corresponding plate may be removed. After alignment of the plates 110₁ and 110₂, the brazing process may be completed. For example, temperature at or above the melting temperature of the braze sheets may be applied to the gas distribution plate 100, to melt the braze sheets and join the plate 110₁ with the plate 110₂.

[0050] In a diffusion bonding method, each plate of the gas distribution plate 100 may be stacked and the holes of each plate may be aligned. For example, the plate 110₁ may be stacked with plate 110₂ and each of the holes 112₁ may be aligned with a respective one of the holes 112₂. After stacking the plates and aligning the holes, the

diffusing bonding process may be completed. Further, aligning the holes may include orienting the plates such that the rolling directions of the raw material of each of the plates are aligned. Orienting the rolling directions of the plates may ensure that any mismatches in material properties based on the direction of the raw material for plates does not impact the bonding and performance of the gas distribution plate. The rolling direction may be parallel to the structural lines on the surface of the plates created during as a result of the manufacture process utilized to create the plates.

[0051] At operation 560, the gas distribution plate formed by bonding the first and second plates is cleaned. For example, in one embodiment, after the completion of the bonding process, the gas distribution plate may be cleaned using any suitable chemical cleaning process. At operation 570, the gas distribution plate 100, 400 may be coated with an oxide, forming a coating on the gas distribution plate, using an atomic layer deposition (ALD) method, or any other process that is able to deposit a layer on the gas distribution plate 100, 400 such that a processing gas may still pass through the interconnected holes. For example, the gas distribution plate 100, 400 may be coated with an oxide, such as Aluminum oxide or Yttrium oxide, among others.

[0052] Figure 6 illustrates a schematic sectional view of a processing chamber 600 according to one embodiment. The processing chamber 600 may be used to process one or more substrates 640 therein, including the processes of depositing a material on the substrate 640, heating of the substrate 640, etching of the substrate 640, or combinations thereof. The processing chamber 600 may be an atomic layer deposition (ALD) chamber. Further, the processing chamber 600 may be a chemical vapor deposition (CVD) processing chamber, a plasma-enhanced chemical vapor deposition (PECVD) processing chamber, or a physical vapor deposition (PVD) processing chamber, among others.

[0053] In one or more embodiments, the processing chamber 600 has an internal region 611 that includes a substrate support 642 disposed therein to support a substrate 640. The substrate support 642 includes a heating element 618 and an element that retains the substrate 640 on a top surface 544 of the substrate support 642, such as an

electrostatic chuck, a vacuum chuck, a substrate retaining clamp, or the like. The substrate support 642 may be coupled to and movably disposed in the internal region 611 by a stem 610 connected to a lift system that moves the substrate support 642 between an elevated processing position and a lowered position that facilitates transfer of the substrate 640 to and from the processing chamber 600 through an opening 624.

[0054] The processing chamber 600 may include a gas supply source 626. In one or more embodiment, the gas supply source 626 may include a mass flow control (MFC) device, disposed between a gas source and the internal region 611 to control a flow rate of process gas or gasses from the gas source to the gas distribution plate 100 of a showerhead assembly 616 used for distributing the process gasses across the internal region 611. For example, the process gas may flow through gas inlet 614 and through the holes of the gas distribution plate 100. The showerhead assembly 616 is coupled to the processing chamber 600. For example, the showerhead assembly 616 may be coupled to the processing chamber 600 to position the gas distribution plate 100 above the substrate 640. The gas distribution plate 100 may be centered over the substrate 640. Further, the gas distribution plate 100 may be larger than the substrate 640 such that the edges of the gas distribution plate 100 extend beyond the edges of the substrate 340. The showerhead assembly 616 may be connected to a RF power source for generating a plasma in the internal region 611 from a process gasses. Moreover, a deposition process may be utilized to process the substrate 640 at a processing pressure to deposit or grow a film onto the substrate 640.

[0055] The stem 610 is configured to move the substrate support 642 to an elevated processing position to process the substrate 640. Further, a vacuum pump 657 may be coupled to the internal region 611 and control the pressure within the internal region 611.

[0056] A process gas, such as a deposition gas or cleaning chemistry, may be supplied from a gas supply source 627 into the internal region 611 through the gas inlet 613 of the processing chamber 600. Further, the process gas may exit the process gas region through the gas outlet 636. Removal of the process gas, including cleaning

chemistry, through the gas outlet 636 is facilitated by a vacuum pump 657 coupled to the gas outlet 636.

[0057] The above-described processing chamber 600 can be controlled by a processor based system controller, such as controller 630. For example, the controller 630 is configured to control flow of various precursor gases, process gases, and purge gases, during different operations of a substrate processing sequence. By way of further example, the controller 630 is configured to control feeding of gases, lamp operation, or other process parameters, among other controller operations.

[0058] The controller 630 is generally used to facilitate the control and automation of the components within the processing chamber 600. The controller 630 can be, for example, a computer, a programmable logic controller, or an embedded controller. The controller 630 typically includes a central processing unit (CPU) 632 memory 634, and support circuits for inputs and outputs (I/O). The CPU 632 may be one of any form of computer processors that are used in industrial settings for controlling various system functions, substrate movement, chamber processes, and control support hardware (e.g., sensors, motors, heaters, etc.), and monitor the processes performed in the processing chamber 600. The memory 634 is connected to the CPU 632, and may be one or more of a readily available non-volatile memory, such as random access memory (RAM), flash memory, read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, local or remote. Software instructions and data can be coded and stored within the memory for instructing the CPU 632. The support circuits are also connected to the CPU 632 for supporting the processor in a conventional manner. The support circuits may include cache, power supplies, clock circuits, input/output circuitry, subsystems, and the like. A program (e.g., software routine or computer instructions) readable by the controller 630 determines which tasks are performable by the components in the processing chamber 600. Preferably, the program is software readable by the processor within the controller 630 that includes code to perform tasks relating to monitoring, execution and control of the delivery and control of the process variables utilized in one or more the processes performed within the processing chamber 600, and the movement, support, and/or positioning of the

substrate 640 and other components within the processing chamber 600 along with the various process tasks and various sequences being controlled the by controller 630.

[0059] A gas distribution plate may be formed to increase in the uniformity of the process gas applied to a substrate during processing of the substrate. The gas distribution plate may be formed by joining two or more plates together. Each of the plates may have a plurality of holes formed therein, and each of the holes in a first one of the plates is aligned with a respective hole in a second one of the plates. When the plates are joined, the aligned holes form a plurality of interconnected holes. Further, by forming the holes in thinner plates which are joined to generate the gas distribution plate, the holes may have a higher aspect ratio than if the holes were formed in a thicker gas distribution plate formed from a single plate. Further, the number of holes that may be formed in each plate may be greater than the total number of holes that may be formed in a gas distribution plate formed from a single plate.

[0060] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention 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 gas distribution plate for a showerhead assembly, the gas distribution plate comprising:

a first plate comprising a first plurality of holes, wherein each of the first plurality of holes has a diameter of at least about 100 μm ; and

a second plate coupled to the first plate, the second plate comprising a second plurality of holes, each of the second plurality of holes has a diameter of at least about 100 μm , wherein each of the first plurality of holes is aligned with a respective one of the second plurality of holes forming a plurality of interconnected holes, wherein each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes.

2. The gas distribution plate of claim 1, wherein each of the plurality of interconnected holes has an aspect ratio of at least about 25 to 1.

3. The gas distribution plate of claim 1, wherein each of the first plurality of holes and each of the second plurality of holes has a diameter of about 100 μm to about 600 μm .

4. The gas distribution plate of claim 1, wherein at least one of each of the first plurality of holes and each of the second plurality of holes has a uniform diameter and a least one of the first plurality of holes and the second plurality of holes has a non-uniform diameter.

5. The gas distribution plate of claim 1, wherein the first plate and the second plate has a thickness in a range about 100 μm to about 12.7 mm.

6. The gas distribution plate of claim 1, wherein the gas distribution plate further comprises a third plate coupled to the second plate, the third plate comprising a third

plurality of holes, wherein each of the third plurality of holes is aligned with a respective one of the first plurality of holes and a respective one of the second plurality of holes.

7. A method for forming a showerhead, the method comprising:
 - generating a first plurality of holes in a first plate, each of the first plurality of holes has a diameter of at least about 100 μm ;
 - generating a second plurality of holes in a second plate, each of the second plurality of holes has a diameter of about 100 μm ;
 - aligning each of the first plurality of holes with a respective one of the second plurality of holes to generate a plurality of interconnected holes, wherein each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes; and
 - bonding the first plate to the second plate.
8. The method of claim 7, wherein bonding the first plate to the second plate comprises one of diffusion bonding and brazing the first plate to the second plate.
9. The method of claim 7, wherein each of the plurality of interconnected holes has an aspect ratio of about 25 to 1, and wherein each of the first plurality of holes and each of the second plurality of holes has a diameter in a range of about 100 μm to about 600 μm .
10. The method of claim 7 further comprising:
 - aligning a rolling direction of the first plate with a rolling direction of the second plate; and
 - coating the bonded first plate and second plate with an atomic layer deposition (ALD) process.
11. A processing chamber comprising:
 - a showerhead assembly comprising:
 - a gas distribution plate comprising:

a first plate comprising a first plurality of holes, wherein each of the first plurality of holes has a diameter of at least about 100 μm ;

a second plate coupled to the first plate, the second plate comprising a second plurality of holes, each of the second plurality of holes has a diameter of at least about 100 μm , wherein each of the first plurality of holes is aligned with a respective one of the second plurality of holes forming a plurality of interconnected holes, wherein each of the plurality of interconnected holes is isolated from each other of the plurality of interconnected holes;

a substrate support configured to support a substrate; and

a gas supply fluidly coupled with the showerhead assembly and configured to provide a process gas to the showerhead assembly.

12. The processing chamber of claim 11, wherein each of the plurality of interconnected holes has an aspect ratio of at least about 25 to 1.

13. The processing chamber of claim 11, wherein each of the first plurality of holes and each of the second plurality of holes has a uniform diameter.

14. The processing chamber of claim 11, wherein a diameter of the first plurality of holes differs from a diameter of the second plurality of holes.

15. The processing chamber of claim 11, where a least one of the first plurality of holes and the second plurality of holes has a non-uniform diameter.

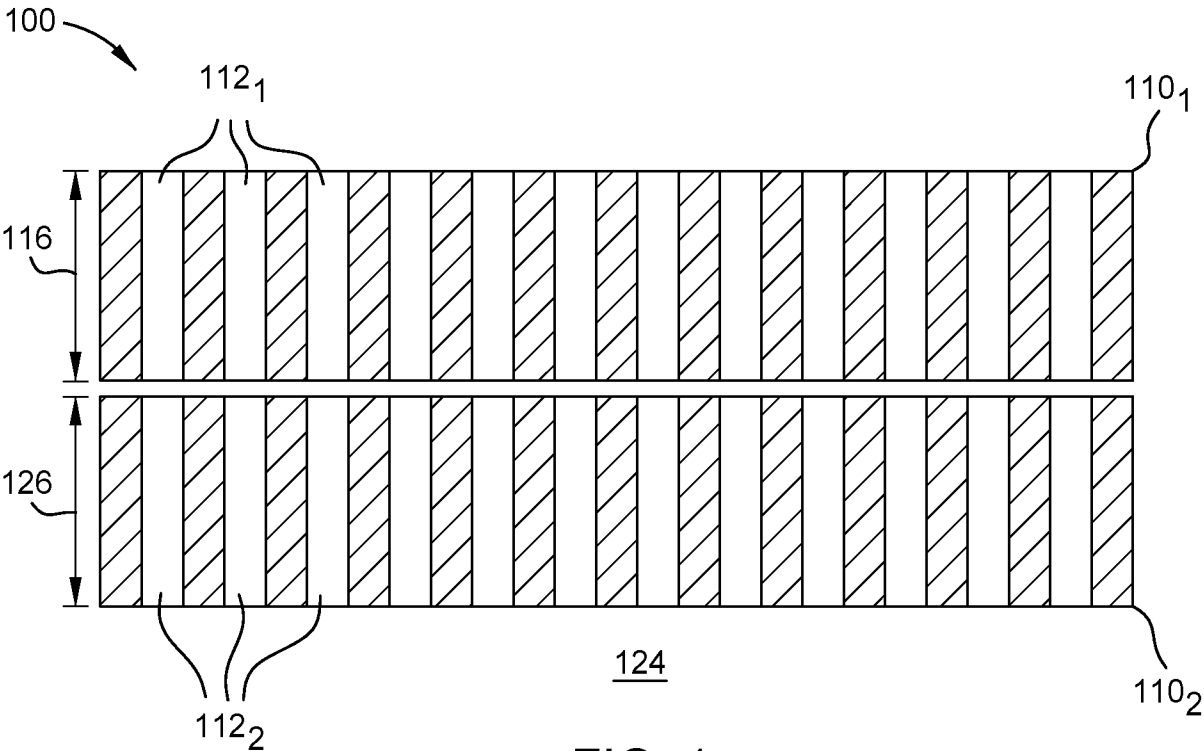


FIG. 1

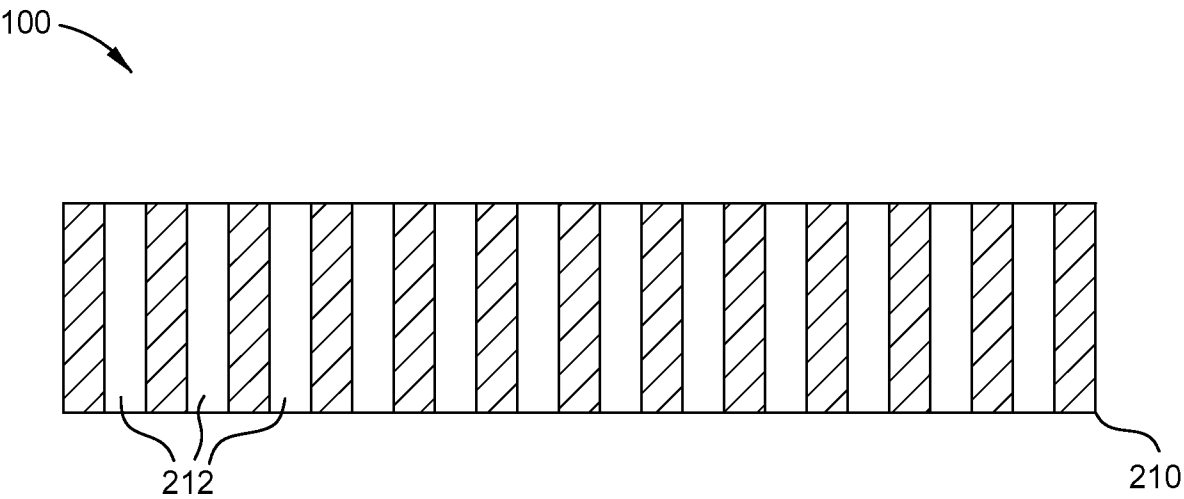


FIG. 2A

2/8

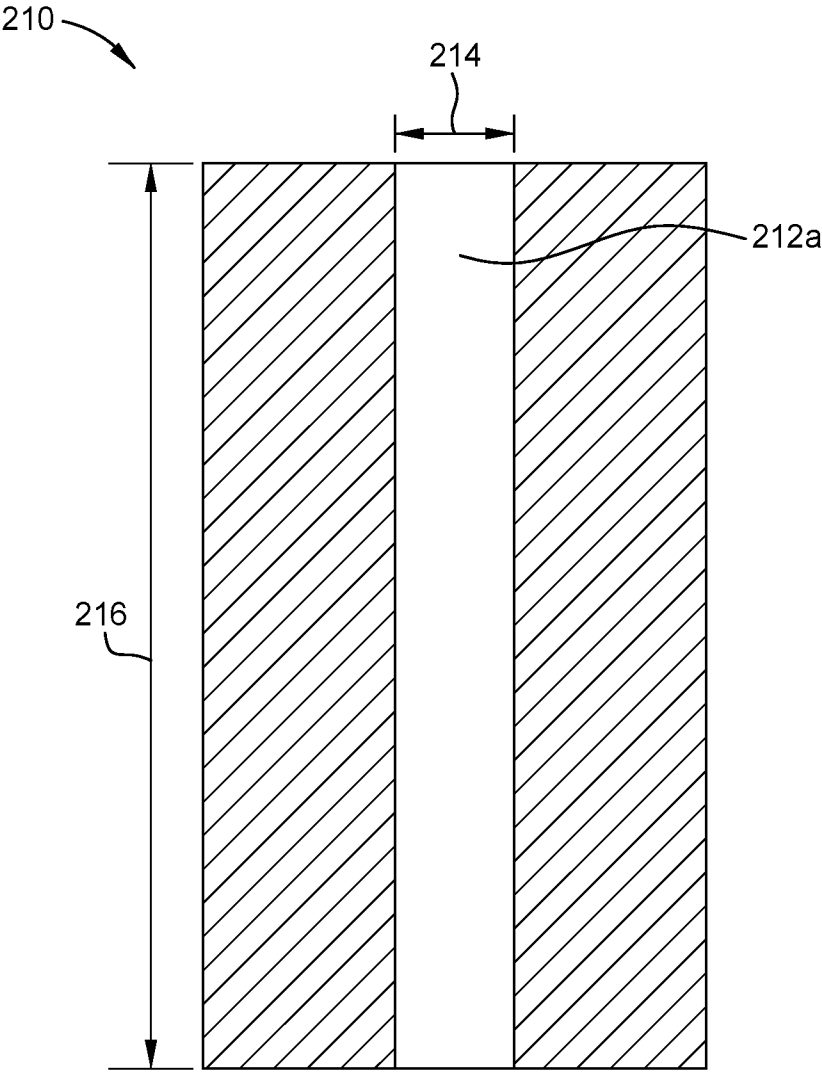


FIG. 2B

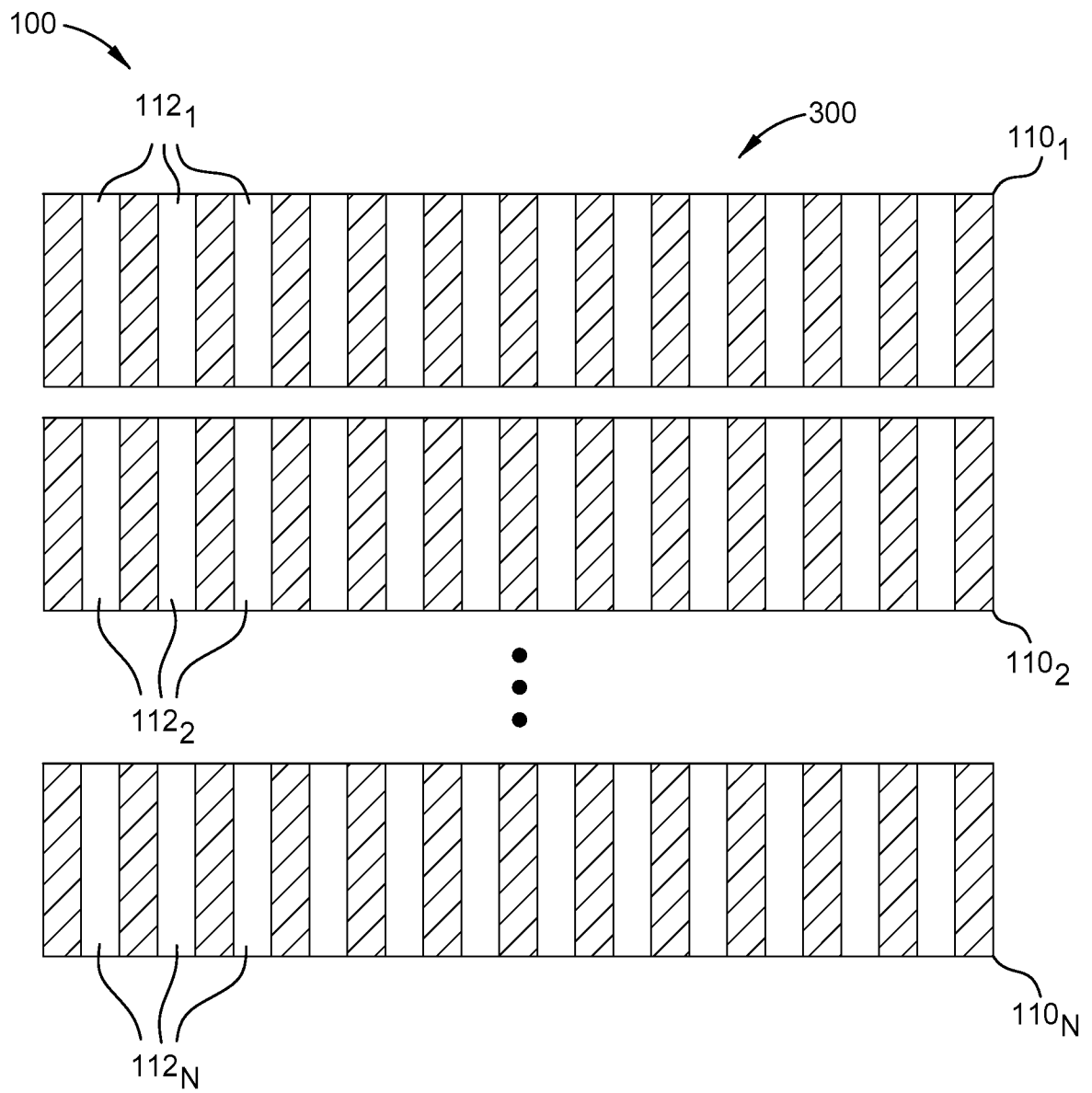


FIG. 3

4/8

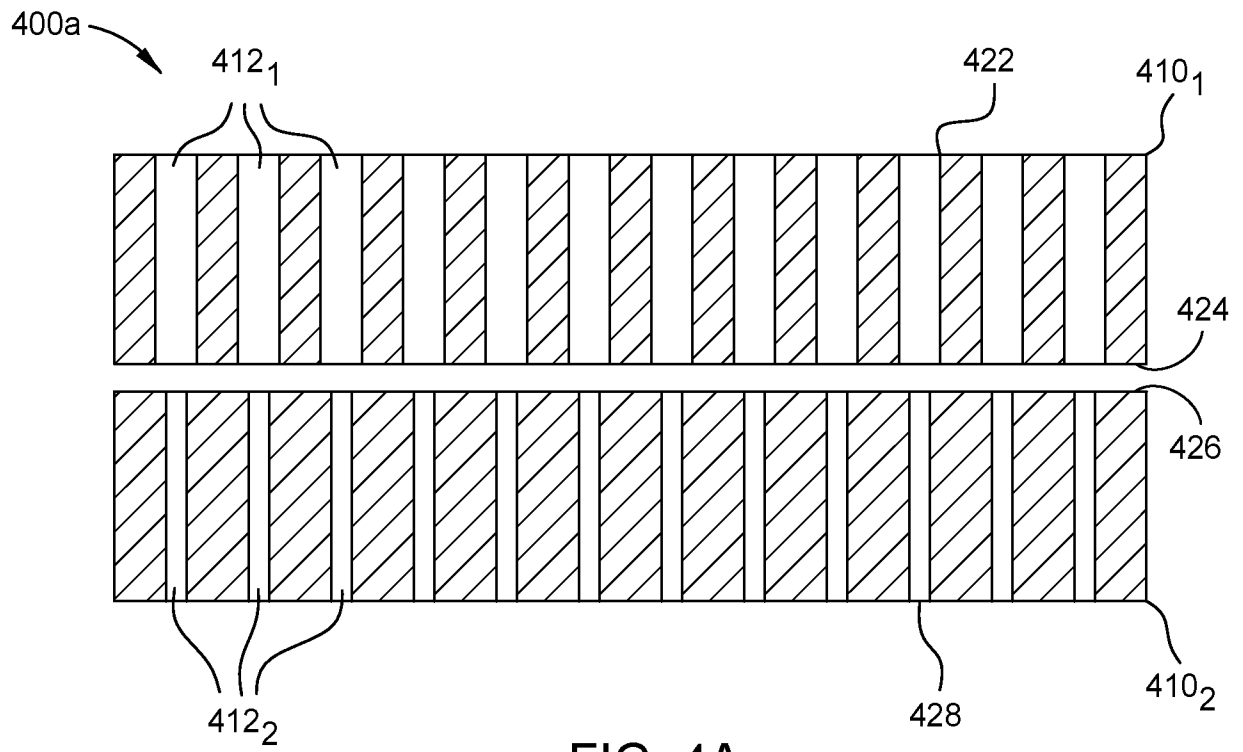


FIG. 4A

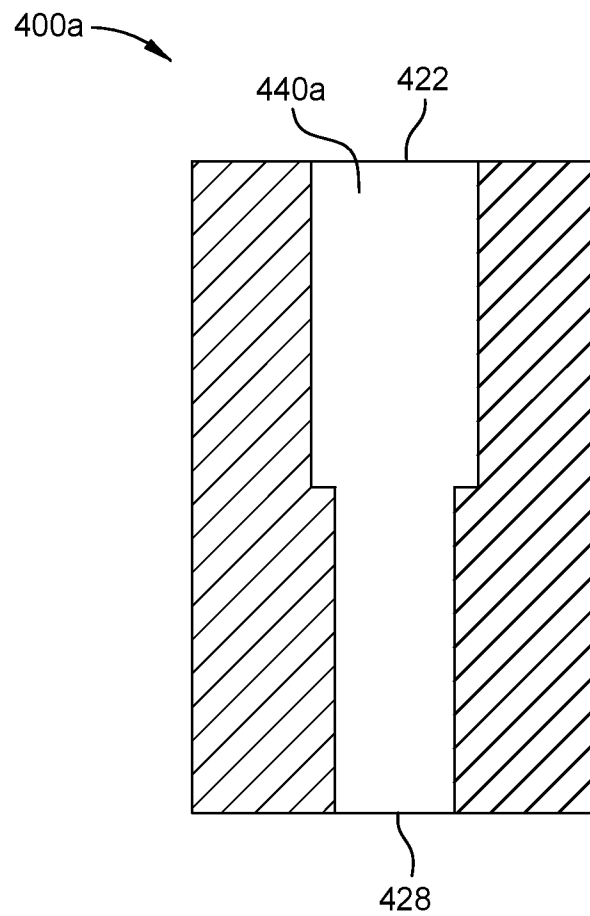


FIG. 4B

5/8

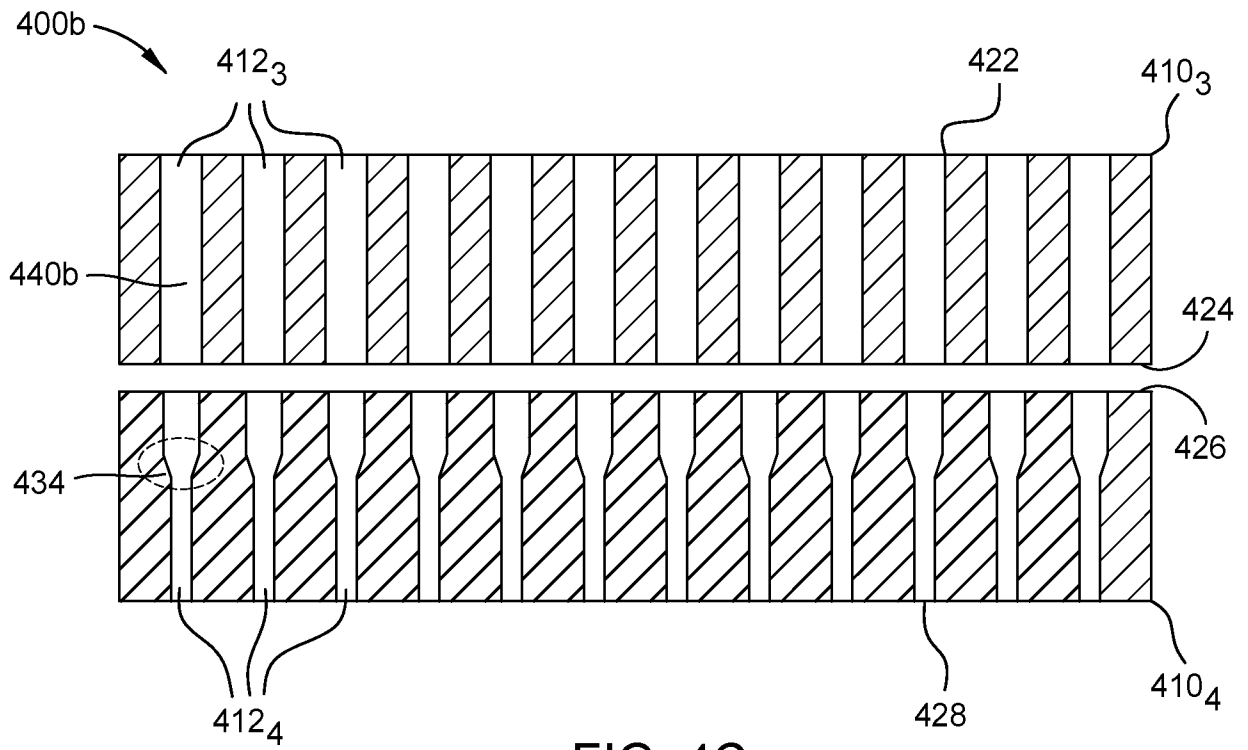


FIG. 4C

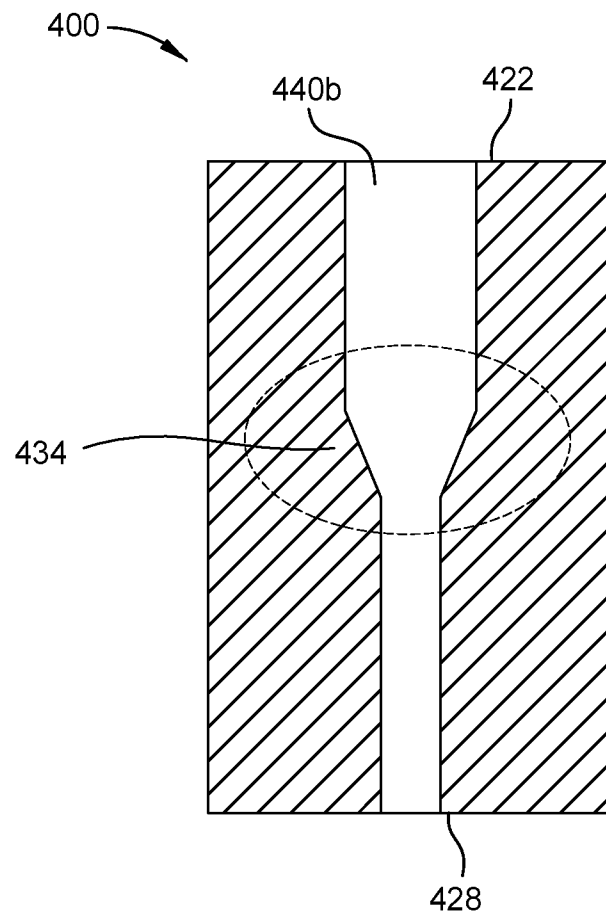
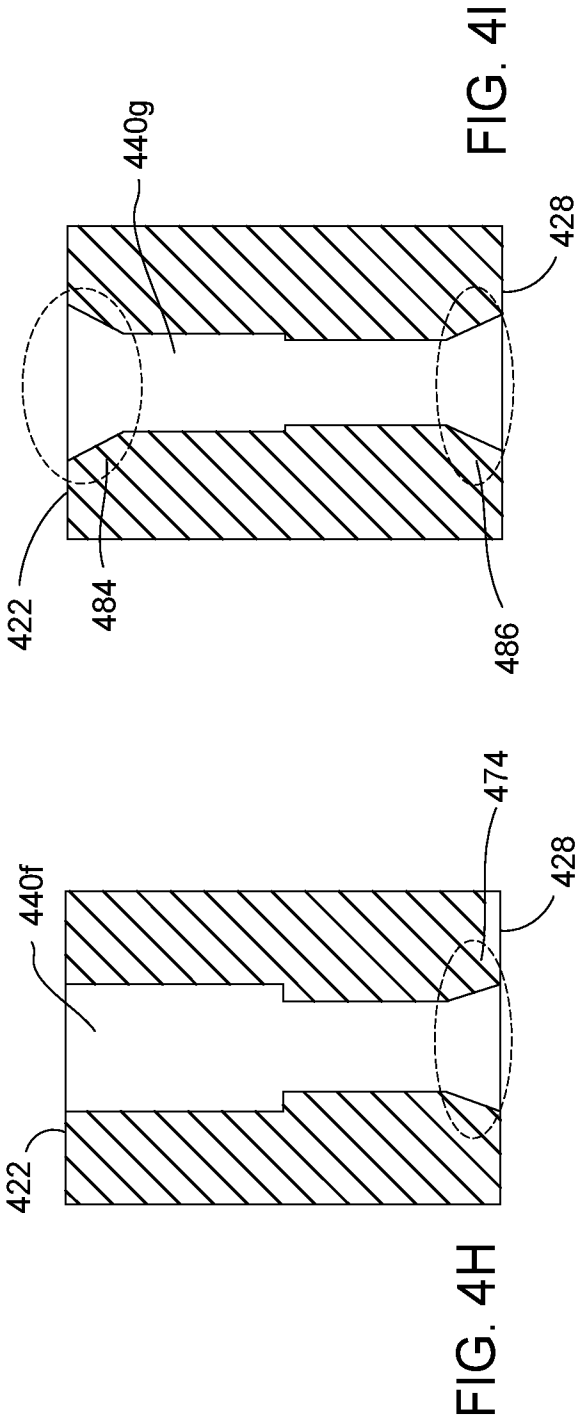
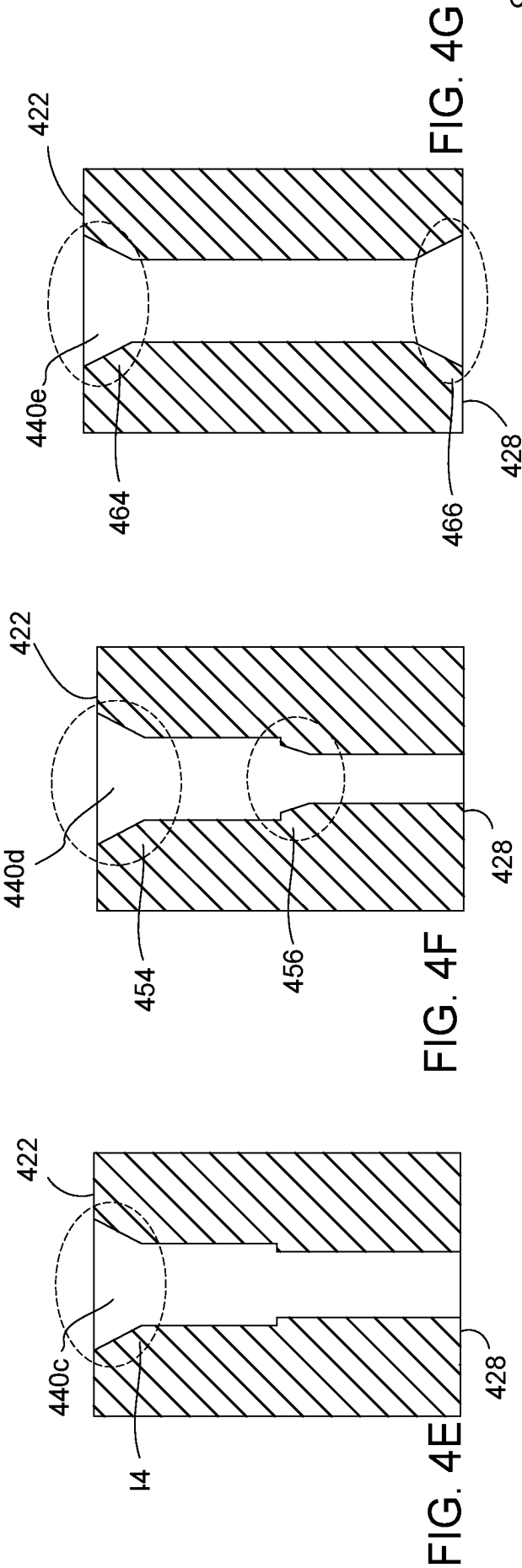


FIG. 4D



7/8

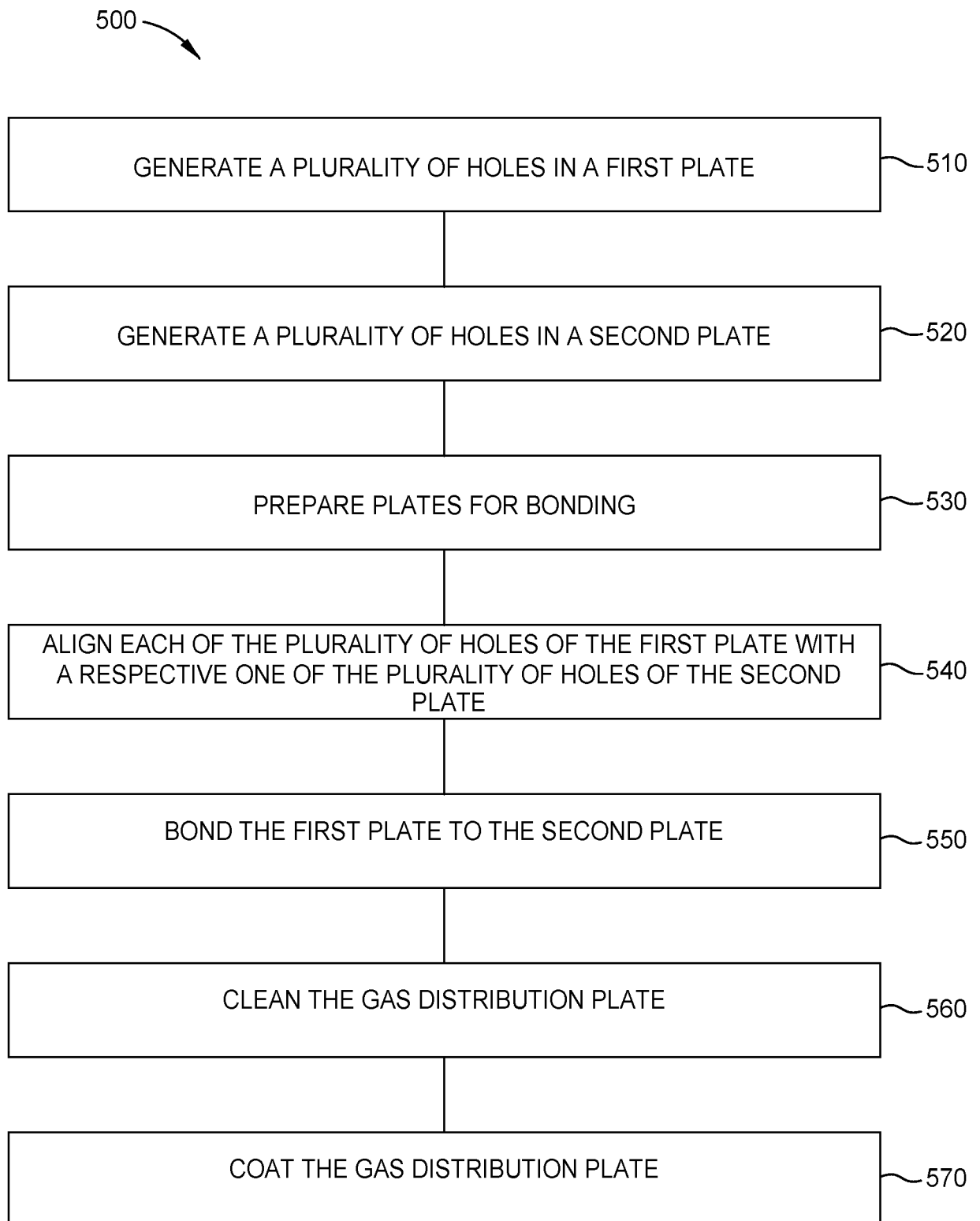


FIG. 5

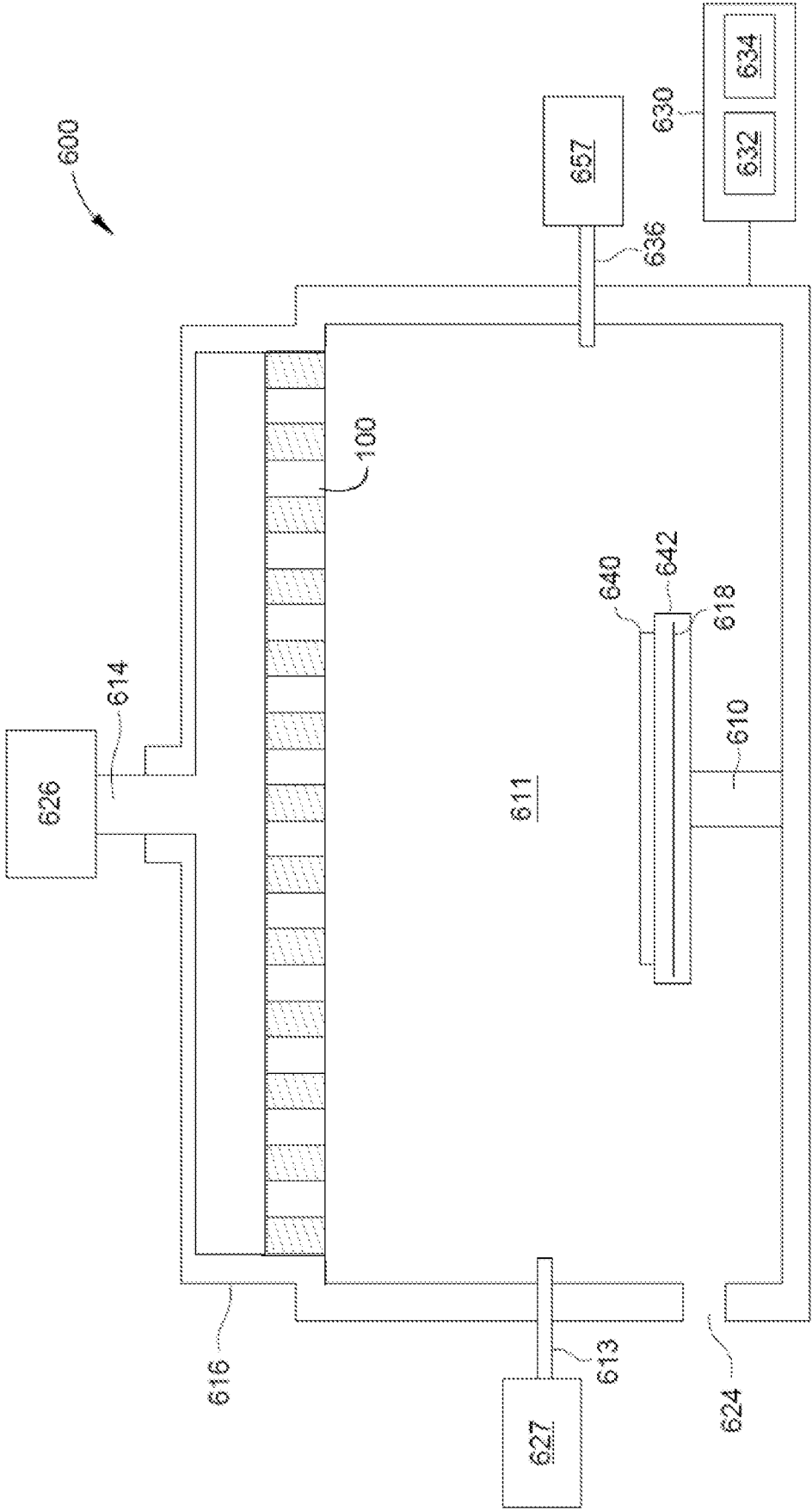


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/020070**A. CLASSIFICATION OF SUBJECT MATTER****C23C 16/455(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 16/455; B05B 15/00; C23C 16/00; H01L 21/02; H01L 21/205; H01L 21/306

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: showerhead, gas distribution, diffuser, chamber, hole, density, high aspect ratio, uniformity, plate, burr, diameter

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2008-0202688 A1 (WU et al.) 28 August 2008 paragraphs [0035]-[0039], [0048], claims 1, 7 and figures 2a-2b, 3a-3b, 9	1-15
A	US 5624498 A (LEE et al.) 29 April 1997 column 3, line 40 - column 4, line 67 and figures 1-3	1-15
A	US 2008-0264566 A1 (KIM et al.) 30 October 2008 paragraphs [0033]-[0041] and figure 1	1-15
A	US 2012-0222815 A1 (SABRI et al.) 06 September 2012 paragraphs [0066]-[0075] and figure 2E	1-15
A	KR 10-2018-0054892 A (APPLIED MATERIALS, INC.) 24 May 2018 paragraphs [0025]-[0026], claim 1 and figure 2a	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

"D" document cited by the applicant in the international application

"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)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"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

"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

"&" document member of the same patent family

Date of the actual completion of the international search

29 June 2020 (29.06.2020)

Date of mailing of the international search report

30 June 2020 (30.06.2020)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

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

Facsimile No. +82-42-481-8578

Authorized officer

LEE, Eon Su

Telephone No. +82-42-481-8539



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/020070

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0202688 A1	28/08/2008	CN 100577866 C CN 101255552 A JP 2008-211183 A JP 3178150 U KR 10-0950115 B1 KR 10-2008-0079584 A US 7992518 B2	06/01/2010 03/09/2008 11/09/2008 06/09/2012 30/03/2010 01/09/2008 09/08/2011
US 5624498 A	29/04/1997	JP 07-201762 A KR 10-1995-0020993 A	04/08/1995 26/07/1995
US 2008-0264566 A1	30/10/2008	KR 10-0599056 B1 US 2007-0020943 A1 US 7405164 B2 US 8551288 B2	04/07/2006 25/01/2007 29/07/2008 08/10/2013
US 2012-0222815 A1	06/09/2012	CN 103403843 A CN 103403843 B CN 106884157 A CN 106884157 B JP 2014-509783 A JP 5933602 B2 KR 10-1843609 B1 KR 10-1937115 B1 KR 10-2014-0011364 A KR 10-2018-0037284 A SG 10201602599 A SG 192967 A1 TW 201250827 A TW 201709322 A TW I566295 B TW I616949 B US 10400333 B2 US 2016-0348244 A1 US 9441296 B2 WO 2012-122054 A2 WO 2012-122054 A3	20/11/2013 14/12/2016 23/06/2017 21/06/2019 21/04/2014 15/06/2016 14/05/2018 09/01/2019 28/01/2014 11/04/2018 30/05/2016 30/09/2013 16/12/2012 01/03/2017 11/01/2017 01/03/2018 03/09/2019 01/12/2016 13/09/2016 13/09/2012 27/12/2012
KR 10-2018-0054892 A	24/05/2018	CN 108140550 A JP 2018-533207 A TW 201713794 A US 10378108 B2 US 2017-0101713 A1 US 2019-0271082 A1 WO 2017-062087 A1	08/06/2018 08/11/2018 16/04/2017 13/08/2019 13/04/2017 05/09/2019 13/04/2017