SHOWERHEAD WITH IMPROVED SUPPORTING POSTS

BACKGROUND

[0001] Semiconductor processing tools can include components designed to distribute processing chemicals in a relatively even manner across a substrate. Such components are commonly referred to in the industry as "showerheads." Showerheads typically include a faceplate that fronts a plenum. The faceplate includes a plurality of outlet holes that allow processing chemicals in the plenum to flow through the faceplate and over a surface of the substrate. The outlet holes are arranged such that the processing gas can be distributed across the wafer surface.

SUMMARY

[0002] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

[0003] One example provides a showerhead for a substrate processing tool. The showerhead comprises a faceplate comprising a plurality of outlet holes; a backplate coupled to the faceplate, the backplate comprising a plurality of post access holes; a plenum between the faceplate and backplate; and a plurality of posts connecting the faceplate and the backplate, each post of the plurality of posts extending from the faceplate into a corresponding post access hole in the backplate, each post comprising a post shoulder recessed within the backplate relative to a plenum-facing surface of the backplate, and each post having a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of a post accommodation portion of the corresponding post access hole into which the post extends.

[0004] In some such examples, a length of each post between the faceplate and the post shoulder is within a range of 0.25 inch to 0.75 inch.

[0005] In some such examples, alternatively or additionally a recessed length of each post between the plenum-facing surface of the backplate and the post shoulder is within a range of 0.1 inch to 0.5 inch.

[0006] In some such examples, alternatively or additionally the post diameter of each post is within a range of 0.1 inch to 0.3 inch.

[0007] In some such examples, alternatively or additionally a difference between the post diameter of each post and the hole diameter of each post access hole is within a range of 0.001 inch to 0.05 inch.

[0008] In some such examples, alternatively or additionally each post is integral with the faceplate and welded to the backplate.

[0009] In some such examples, alternatively or additionally the backplate comprises a central upper portion welded to a stem portion, and wherein a weld joint between the central upper portion and the stem portion comprises a rotary friction weld (RFW) joint.

[0010] In some such examples, alternatively or additionally a rim weld joint between the backplate and the faceplate comprises a friction stir weld (FSW) joint.

[0011] In some such examples, alternatively or additionally an outlet hole of the plurality of outlet holes comprises a chamfered edge at a plenum-facing entrance to the outlet hole.

[0012] In some such examples, alternatively or additionally a substrate facing surface of the faceplate has a concave profile.

[0013] In some such examples, alternatively or additionally a concavity depth between an edge of the substrate facing surface of the faceplate and a center of the substrate facing surface of the faceplate is within a range of 0.001 inch to 0.05 inch.

[0014] In some examples, alternatively or additionally a substrate facing surface of the faceplate has a convex profile.

[0015] Another example provides a substrate processing tool. The substrate processing tool comprises a processing chamber; and a showerhead to emit processing chemicals into the processing chamber, the showerhead comprising: a faceplate comprising a plurality of outlet holes; a backplate coupled to the faceplate, the backplate comprising a plurality of post access holes; a plenum between the faceplate and backplate; and a plurality of posts connecting the faceplate and the backplate, each post of the plurality of posts extending from the faceplate into a corresponding post access hole in the backplate, each post comprising a post shoulder recessed within the backplate relative to a plenum-facing surface of the backplate, and each post having a post diameter between the faceplate and the post shoulder that is smaller than a hole

diameter of a post accommodation portion of the corresponding post access hole into which the post extends.

[0016] In some such examples, alternatively or additionally a length of each post between the faceplate and the post shoulder is within a range of 0.25 inch to 0.75 inch.

[0017] In some such examples, alternatively or additionally a recessed length of each post between the plenum-facing surface of the backplate and the post shoulder is within a range of 0.1 inch to 0.5 inch.

[0018] In some such examples, alternatively or additionally the post diameter of each post is within a range of 0.1 inch to 0.3 inch.

[0019] In some such examples, alternatively or additionally a difference between the post diameter of each post and the hole diameter of each post access hole is within a range of 0.001 inch to 0.05 inch.

[0020] In some such examples, alternatively or additionally the backplate comprises a central upper portion welded to a stem portion, and a weld joint between the central upper portion and the stem portion comprises a rotary friction weld (RFW) joint.

[0021] In some such examples, alternatively or additionally a rim weld joint between the backplate and the faceplate comprises a friction stir weld (FSW) joint.

[0022] Another example provides a method for assembling a showerhead for a substrate processing tool. The method comprises: inserting a plurality of posts of a faceplate into a plurality of post access holes of a backplate to define a plenum between the faceplate and the backplate, such that each post extends from the faceplate into a corresponding post access hole in the backplate, and a post shoulder of each post is recessed within the backplate relative to a plenum-facing surface of the backplate, each post having a post having a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of a post accommodation portion of the corresponding post access hole into which the post extends; and welding each of the plurality of posts to the backplate within each post access hole.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 shows a schematic depiction of an example substrate processing tool comprising a showerhead.

[0024] FIG. 2A shows a perspective view of an example showerhead.

[0025] FIG. 2B shows a sectional view of the example showerhead of FIG. 2A.

[0026] FIG. 2C shows a first magnified sectional view of the example showerhead of FIG. 2A.

[0027] FIG. 2D shows a second magnified sectional view of the example showerhead of FIG. 2A.

[0028] FIG. 2E shows an overhead view of the example showerhead of FIG. 2A.

[0029] FIG. 3 shows a view of a plurality of outlet holes in a plenum-facing surface of a showerhead faceplate.

[0030] FIG. 4 schematically illustrates two portions of an example showerhead backplate welded together with a rotary friction weld (RFW) joint.

[0031] FIG. 5 schematically depicts a showerhead faceplate having a concave profile on the substrate facing surface of the faceplate.

[0032] FIG. 6 illustrates an example method for assembling a showerhead for a substrate processing tool.

DETAILED DESCRIPTION

[0033] The term “atomic layer deposition” (ALD) generally represents a process in which a film is formed on a substrate in one or more individual layers by sequentially adsorbing a precursor to a substrate and then chemically transforming the adsorbed precursor to form a film layer.

[0034] The term “backplate” generally represents a component part of a showerhead. The backplate, together with a faceplate, defines a plenum of the showerhead. The backplate faces away from a substrate holder of a processing tool.

[0035] The term “chamfered edge” generally represents a corner of a structure where two surfaces meet, wherein the corner is sloped instead of square.

[0036] The term “chemical vapor deposition” (CVD) generally represents a process in which a film is formed on a substrate by exposing the substrate to a flow of reactive gas phase precursors.

[0037] The term "etch" generally represents removal of a material from a substrate. A wet etch uses a liquid phase solution to remove material from a substrate. A dry etch uses gas phase chemicals and/or plasmas to remove material from a substrate.

[0038] The term "faceplate" generally represents a part of a showerhead that faces toward a substrate holder of a processing tool. A faceplate comprises outlet holes to emit processing chemicals from a plenum located behind the faceplate toward a substrate.

[0039] The term "film" or "film layer" may refer to a thin layer of material deposited on the substrate (e.g., semiconductor wafer), and may include dielectrics, conductive materials, and/or semiconductor materials.

[0040] The term "outlet hole" generally represents an opening in a showerhead through which processing chemicals are emitted from a plenum toward a substrate during substrate processing.

[0041] The term "plenum" generally represents a volume of space between a faceplate and a backplate. Processing chemicals flow into the plenum through a processing chemical inlet, and flow out of the plenum toward a substrate through a plurality of outlet holes. The outlet holes extend through a faceplate to fluidly connect the plenum with an environment external to the plenum.

[0042] The term "post" generally represents a structural support that extends between a faceplate and a backplate of a showerhead across a plenum of the showerhead. A post can be formed integrally with a faceplate and welded to the backplate.

[0043] The term "post access hole" generally represents an opening in the backplate of a showerhead into which a post is inserted to thereby attach the backplate to the faceplate.

[0044] The term "post shoulder" generally represents a facet along a post where the post diameter narrows to form a ridge. Portions of the post beyond the post shoulder relative to the faceplate can be welded to the backplate to attach the faceplate to the backplate.

[0045] The term "processing chamber" generally represents an enclosure in which chemical and/or physical processes are performed on substrates. Processing tool components such as a showerhead and a pedestal are located within the processing chamber.

[0046] The term "showerhead" generally represents a structure for distributing processing chemicals across a surface of a substrate. A showerhead can comprise a plenum between a faceplate and a backplate, and plurality of outlet holes formed in the faceplate.

[0047] The term "substrate" generally represents any structure on which a film can be deposited.

[0048] As mentioned above, showerheads are used in many semiconductor processing tools to distribute processing chemicals in a relatively even manner across a substrate. A showerhead can include a faceplate joined to a backplate to define a plenum. Processing chemicals are introduced into the plenum through an inlet in the backplate. The processing chemicals flow from the plenum through a plurality of outlet holes distributed across the faceplate toward the substrate.

[0049] The faceplate can be joined to the backplate at multiple attachment points. For example, a perimeter region of the backplate can be joined to a perimeter region of the faceplate by a welded joint. Further, a plurality of posts can join the faceplate and backplate at multiple locations within the plenum. In some instances, the posts can be formed integrally with the faceplate and welded to the backplate.

[0050] During a substrate processing cycle, a substrate on a pedestal in a processing chamber can be heated to relatively high temperatures. The faceplate, which directly faces the substrate, is heated during such substrate processing. The backplate can be cooled by a fluid cooling system during use. Such a fluid cooling system can attach to a stem portion of the backplate. Thus, a temperature gradient exists along the showerhead from the faceplate to the backplate during substrate processing.

[0051] The temperature gradient can cause the faceplate to thermally expand in a radial direction (across a plane of the faceplate) at a greater rate than the backplate. The greater rate of thermal expansion of the faceplate compared to the backplate can have various mechanical effects. For example, the temperature gradient can cause the backplate to be radially stretched and the faceplate to be radially compressed. This can cause the faceplate to bow away from the backplate.

[0052] The posts that connect the faceplate and the backplate function to resist this bowing effect. However, the greater rate of thermal expansion of the faceplate compared to the backplate can apply strain to the posts. This is because the location at which the post meets the faceplate is displaced by thermal expansion with a larger magnitude radially than the location at which the post meets the backplate. Over many

cycles of heating and cooling, the strain experienced by the posts can pose a risk of fracturing the posts.

[0053] Accordingly, examples are disclosed that relate to showerheads with post designs that can offer improved durability when exposed to repeated heating/cooling cycles. For example, the present disclosure describes example showerheads having a post shoulder that is recessed within the backplate, as opposed to a post shoulder that is within the plenum and abuts the backplate. Furthermore, the diameter of each post between the faceplate and the post shoulder is less than the hole diameter of the post access holes into which the posts extend, such that there is a gap between the sides of each post and the sides of the post access hole into which the post is inserted. By contrast, posts used in conventional showerheads can be shorter in length, have post shoulders that are not recessed within the backplate, and do not include a gap between each post and the sides of each post access hole.

[0054] The use of longer posts and inclusion of a gap between portions of each post and the sides of its corresponding access hole can improve the durability of the showerhead over repeated heating cycles by providing each post with a greater freedom to flex during heating of the showerhead, which reduces the amount of strain on the post for a given thermal expansion differential between the showerhead faceplate and backplate. This can result in less strain on the posts in higher temperature settings compared to showerheads that use conventional post designs, which can result in less cracking or fracturing of the posts. Notably, in some examples, use of recessed post shoulders as described herein may improve showerhead durability without requiring an increase in plenum thickness. Increasing the plenum thickness could undesirably increase the duration of purge or chemistry-transition steps, which can decrease productivity for some processes.

[0055] Referring now to FIG. 1, an example processing tool 100 for processing a substrate is shown. The processing tool 100 can be configured for thermal or plasma-enhanced chemical vapor deposition (CVD), thermal or plasma-enhanced atomic layer deposition (ALD), and/or other substrate processes. It will be understood that, in other examples, a showerhead as described herein may alternatively or additionally be used for suitable substrate etching processes, and is not limited to deposition processes. The processing tool 100 comprises a processing chamber 102 including a showerhead 104. The showerhead 104 comprises a stem 106 connected to the processing chamber. The showerhead 104 also includes a lower portion 110 that extends radially outwardly from

a bottom of the stem 106. As described in more detail below, the showerhead 104 includes a faceplate comprising a plurality of outlet holes, a backplate, and a plenum between the faceplate and the backplate.

[0056] It will be understood that the specific configuration shown in FIG. 1 is non-limiting, and that the arrangements described herein can be applied to a wide variety of different suitable showerheads and substrate processing scenarios. In particular, in some examples, a showerhead as described herein need not include a "stem" or "stem portion," while still including a faceplate and backplate that are joined via posts and define a plenum.

[0057] The processing tool 100 further includes a pedestal 114. The depicted pedestal 114 is configured as an electrostatic chuck pedestal. During operation, a substrate 116 is arranged on the pedestal 114. Electrodes 118 electrostatically attract the substrate 116 during processing to hold the substrate securely. In other examples, other types of pedestals can be used.

[0058] The processing tool 100 is configured to perform plasma-enhanced substrate treatments, such as plasma-enhanced atomic layer deposition (PEALD) and plasma-enhanced chemical vapor deposition (PECVD). Thus, the processing tool 100 includes an RF generating system 120 to generate and output RF power. In this example, the pedestal 114 is configured as a powered electrode, and the showerhead 104 is grounded. In other examples, the showerhead 104 can receive power from the RF generating system 120, and the pedestal 114 can be grounded. The RF generating system 120 includes an RF generator 122 that generates the RF power. The RF generating system 120 further includes a matching and distribution network 124. The substate processing tool further includes an actuator 126 and a lift pin assembly 128. The lift pin assembly includes P lift pins 128, where P is an Integer greater than 2. The actuator 126 and the lift pin assembly 128 are used during loading and unloading of the substrate 116 from the chamber.

[0059] The processing tool 100 further comprises a gas delivery system 130. The gas delivery system 130 includes one or more gas sources 132-1, 132-2, ... , and 132-N (collectively gas sources 132), where N is an integer greater than zero. The gas sources 132 supply one or more processing gases such as deposition precursors, purge gas, etch gas, etc. In some examples, vaporized precursors may also be used (not shown). The gas sources 132 are connected by valves 134-1, 134-2, ... , and 134-N (collectively valves 134), mass flow controllers 136-1, 136-2, ... , and 136-N

(collectively mass flow controllers 136), and valves 138-1, 138-2, ... , and 138-N (collectively valves 138) to a manifold 140. An output of the manifold 140 is fed by the gas delivery system 130 to the processing chamber 102. For example, the output of the manifold 140 is fed to the showerhead 104.

[0060] A heater controller 142 ("HC") is connected to resistive heaters arranged in the pedestal 114. The heater controller 142 can be used to control a temperature of the pedestal 114. In addition, the pedestal 114 can include internal channels (not shown) to flow a fluid from a fluid source (not shown) to provide further control of the pedestal and substrate temperatures.

[0061] A valve 150 and pumping system 152 can be used to evacuate reactants and products from the processing chamber 102 and/or to control pressure in the processing chamber. A controller 160 can be used to control the various components of the processing tool 100 described herein. For example, the controller 160 can cause a robot arm 170 to load the substrate 116 onto the pedestal 114, and unload the substrate 116 from the pedestal 114. The controller 160 communicates with the gas delivery system 130 to control supply of process, purge and/or inert gases. The controller communicates with the valve 150 and pump 152 to control pressure within the processing chamber and/or evacuation of reactants. The controller 160 also causes a voltage source 172 to output voltage to the electrodes 118 to clamp and unclamp the substrate.

[0062] FIGS. 2A-2E show different views of an example showerhead 200. More particularly, FIG. 2A shows a perspective view of showerhead 200. FIG. 2B shows a sectional view of showerhead 200. FIG. 2C shows a first magnified sectional view of showerhead 200. FIG. 2D shows a second magnified view of showerhead 200. FIG. 2E shows an overhead view of showerhead 200. The showerhead 200 is an example of the showerhead 104 of FIG. 1. With reference to FIGS. 2A and 2B, the showerhead 200 comprises a faceplate 202 and a backplate 204. Referring to the sectional view of FIG. 2B, a plenum 206 is located between the faceplate 202 and the backplate 204. The faceplate 202 comprises a plurality of outlet holes 208 that lead from the plenum 206 to an exterior of the showerhead 200. In some examples, a showerhead may have on the order of hundreds or thousands of outlet holes. The outlet holes 208 of FIGS 2B, 2C, and 3 are shown schematically and are not drawn to scale.

[0063] The plenum 206 receives processing chemicals through a processing chemical inlet 210. Though not shown in FIG. 2B, in some examples, a showerhead

according to the examples described herein can include a baffle in the plenum that the processing chemicals impinge upon. Use of such a baffle can serve to prevent a higher flow of processing chemicals from being emitted from outlet holes 208 immediately below the processing chemical inlet 210 than from other outlet holes.

[0064] In some examples, the faceplate 202 and the backplate 204 can be joined at a welded joint 212 at a perimeter of the plenum 206. In some examples, the welded joint is a rim weld joint comprising a friction stir weld (FSW) joint. Friction stir welding is a non-melting joining process, and has no heat affected zone where material can be weakened in a melt-joining method. Further, the penetration depth of friction stir welding can be controlled more precisely than a melt-joining method. This is at least due to the friction stir welding penetration depth being controlled by the stir bit, rather than by delivered power. Also, friction stir welding can achieve deeper penetration than melt-joining processes while generating less faceplate deformation from residual stress than melt-joining methods. Friction stir welding can increase an operational lifetime of the rim joint between the faceplate and the backplate compared to melt-joining methods.

[0065] Continuing with FIG. 2B, the showerhead 200 comprises a plurality of posts 214 that connect the faceplate 202 and the backplate 204. Two posts 214A and 214B are shown in sectional view in FIG. 2B The posts 214 can be formed integrally with the faceplate 202 and welded to the backplate 204. The backplate 204 comprises a plurality of post access holes 216, and each post 214 extends from the faceplate 202 into a corresponding post access hole 216 in the backplate. FIG. 2B shows post access holes 216A and 216B corresponding to posts 214A and 214B. The post access holes 216 allow the posts 214 to be welded to the backplate 204 during showerhead manufacturing. For example, electron beam welding can be used to weld the posts 214 by placing each posts 214 into a corresponding post access holes 216, and directing an electron beam into the post access hole 216 to fuse the post with the backplate.

[0066] Although only two posts and corresponding post access holes are shown in FIG. 2B, showerhead 200 includes additional posts and corresponding post access holes that are not visible in the sectional view of FIG. 2B. FIG. 2E provides an overhead view of the faceplate 202 and backplate 204 of showerhead 200 (e.g., depicting a plenum-distal surface of backplate 204). Several components of the showerhead, including the stem portion, are omitted in the view shown in FIG. 2E for the sake of visual clarity. As shown, showerhead 200 includes several different post access holes

216. The faceplate 202 of showerhead 200 includes corresponding posts that extend into the post access holes 216 to connect the faceplate to the backplate. It will be understood, however, that the specific quantity and distribution of posts used in showerhead 200 is non-limiting. In other examples, other numbers and arrangements of posts and corresponding post access holes can be used. For certain operations a lesser number of posts can be advantageous compared to a greater number of posts, as the use of too many posts can impede the flows of processing chemicals within the plenum. Further, no outlet hole can be placed under the posts. Therefore, the use of a greater number of posts can correspond to the use of fewer outlet holes.

[0067] Turning now to FIG. 2C, a first magnified sectional view of showerhead 200 is provided, with a closer view of post 214B extending into post access hole 216B. Post 214B includes a post shoulder 218 that is recessed within backplate 204 relative to a plenum-facing surface of the backplate. Though not visible in FIG. 2C, each other post 214 of the showerhead 200 also includes a post shoulder that is recessed within the backplate 204. Portions of the posts beyond the post shoulder relative to the plenum (referred to herein as "joining portions" of the posts) are welded to the backplate. Because the post shoulders 218 are recessed within the backplate, each post 214 includes a segment prior to the post shoulder (referred to herein as a "recessed length" of the post) that extends into the backplate but is not welded to the backplate. This is shown in FIG. 2C as recessed length 219 of post 214B. In some examples, the recessed length of each post between the plenum-facing surface of the backplate and the post shoulder is within a range of 0.1 inch to 0.5 inch, inclusive of the endpoints. This is contrary to posts used in conventional showerheads, where the post shoulder is within the plenum and abuts the plenum-facing surface of the backplate. As such, in conventional designs, substantially all of the post metal that extends into the backplate is welded to the backplate, which can limit the freedom of each post to flex or thermally expand when the showerhead is heated. Recessing the post shoulder within the backplate can beneficially increase the length of the post, increasing its ability to flex and therefore resist strain during repeated thermal cycles, without requiring an increase in the height of the plenum. It will be understood that each post may be recessed to any suitable degree within the backplate – e.g., the recessed portion of the post and the joining portion of the post may each have any suitable length.

[0068] As discussed above, the example showerheads described herein include posts that that are longer than those used in some conventional showerhead designs. In

some examples, a length of each post between a plenum-facing surface of the faceplate and the post shoulder is within a range of 0.25 inch to 0.75 inch, including the endpoints. This length includes the height of the plenum, and the recessed length of the post within the backplate. In some examples, the height of the plenum is within a range of 0.15 inch to 0.35 inch, inclusive of the endpoints. In one example, the height of the plenum is 0.25 inch, and the recessed length of the post is 0.25 inch, such that the length of the post between the faceplate and the post shoulder is 0.5 inch. By contrast, posts used in some conventional showerhead designs can have a length of 0.3 inch or less between the faceplate and the post shoulder, and the post length is equal to the height of the plenum.

[0069] Turning now to FIG. 2D, a second magnified sectional view of showerhead 200 is provided, with a closer view of post 214B extending into post access hole 216B. In this view, it is more visible that each post has a post diameter between the faceplate and the post shoulder that is smaller than the hole diameter of the corresponding post access hole into which the post extends. For instance, a portion of post 214B between the faceplate and post shoulder 218 has a post diameter 220 that is smaller than a hole diameter 221 of a post accommodation portion 223 of post access hole 216B, such that there is a gap between the sides of the post and the sides of the post access hole within the post accommodation portion of the post access hole. The "post accommodation portion" corresponds to the length of the post access hole between the plenum and the area where the joining portion of the post is welded to the backplate (e.g., beyond the post shoulder).

[0070] Furthermore, in this example, each post access hole includes a weld access portion 224 having a larger diameter than the hole diameter 221 of the post accommodation portion 223 of the post access hole. The "weld access portion" may have a diameter that is sufficient to accommodate a welding tool used to affix the faceplate to the backplate via welding of the posts. It will be understood that the diameter of the weld access portion may have any suitable relationship with respect to the diameter of other portions of the post access hole – for instance, in various examples, the diameter of the weld access portion may be larger than, smaller than, or equal to, the diameter of the post accommodation portion or joining portion of the post. While not illustrated, in some examples, a top of one or more posts may protrude beyond the joining portion 222. In some examples, a plug maybe be used to occupy a portion of the 216A/216B cavity shield welding point from debris or particles.

Furthermore, it will be understood that the depiction of post 214B and post access hole 216B in FIG. 2D is simplified and not drawn to scale – for instance, the size of the visible gap between the sides of the post and the sides of the post access hole is exaggerated for the sake of illustration.

[0071] In some examples, the post diameter of each post is within a range of 0.1 inch to 0.3 inch, including the endpoints. In some examples, a difference between the post diameter of each post and the hole diameter of each post access hole is within a range of 0.001 to 0.05 inch, including the endpoints. This difference in diameter can provide each post with additional freedom to flex and/or thermally expand when the showerhead is heated during substrate processing. This can reduce the strain applied to each post, thereby reducing incidences of post cracking or fracturing and prolonging the effective life of the showerhead. For certain operations it is desirable for the difference in diameter between the post access hole not to be too large. While some amount of free space between the sides of each post its corresponding post access hole can be beneficial, having an excessively large gap can allow processing chemicals to build up within the post access holes.

[0072] As discussed above, in some examples, the posts are attached to the backplate by welding each post to the backplate within each post access hole. In the example of FIG. 2D, post 214B comprises a joining portion 222 beyond post shoulder 218, relative to the plenum. The joining portion is welded to the backplate 204 to thereby connect the faceplate to the backplate. In FIG. 2D the post shoulder 218 is illustrated to have a greater diameter than the joining portion 222. In some embodiments, they have substantially the same diameters (+/- 10%). In FIG. 2D the post 214B has uniformed diameter within the recess length 219 (up to the post shoulder 218), however, in some embodiments, the diameter of the post 214B is not uniform. For example, a portion of the post 214B closer to the joining portion 222 may have a greater diameter than a portion of the post 214B closer to the opening of the recess length 219 and vice versa. In some instances, having more material near the post shoulder 218 portion may increase the welding surface while minimizing the material needed for the rest of the post. In some instances, having greater diameter closer to the opening of the recess length 219 may change how plenum gas interacts with the post accommodation portion 223 of the post access hole, and therefore change the gas flow pattern around the one or more posts with such modification.

[0073] In some examples, prior to welding the post to the backplate, a retaining nut is threaded onto the joining portion of the post. The present disclosure is not limited to any specific number of spacing of threads, or any specific shape or size of the retaining nut. In some examples, the retaining nut serves to temporarily hold the faceplate and backplate together during the welding process. As such, in some examples, the bottom of the nut bears on a shoulder in the post access hole, formed by a diameter step in the post access hole. In some examples, the posts described herein include a smaller number of threads than posts used in some conventional showerhead designs. While using some number of threads can be beneficial for affixing a retaining nut to the post, using a relatively smaller number of threads can reduce the incidence of post cracking or fracture.

[0074] As discussed above, a showerhead according to the present disclosure comprises a plurality of outlet holes in the faceplate to emit processing chemicals from the plenum into the external environment. FIG. 3 provides a magnified, partial view of a plenum-facing surface of a showerhead faceplate 300 according to the present disclosure. The faceplate comprises several outlet holes 302A, 302B, and 302C. It will be understood that faceplate 300 includes additional outlet holes not visible in FIG. 3. In this example, each outlet hole 302 comprises a chamfered edge 304 at the plenum-facing entrance to the outlet hole. In other examples, less than every outlet hole comprises a chamfered edge. A "chamfered edge" refers to an edge that is sloped or curved through a chamfering, deburring, edge breaking, and/or other edge treatment processes. This is in contrast to edges with squared and/or untreated corners. In some cases, use of squared and/or untreated corners can contribute to chemical buildup within the outlet holes. Over time, such chemical buildup can eventually clog the outlet hole, and/or result in undesired side reactions with other chemicals. Use of chamfered edges on the plenum-facing entrances to the outlet holes can mitigate such chemical buildup.

[0075] As discussed above, a showerhead according to the present disclosure comprises a backplate connected to a faceplate to define a plenum. The backplate includes a stem that incorporates an inlet, used to introduce processing chemicals into the plenum. As such, the backplate itself comprises a relatively wide and flat portion that defines an upper surface of the plenum (referred to herein as a "central upper portion" of the backplate), and a relatively taller, narrower "stem portion" extending away from the plenum. In some examples, the backplate is formed from a single piece of starting material, such as a block of aluminum. However, this can require a relatively

large piece of starting material, which can increase the expense of manufacturing the showerhead.

[0076] As such, in some examples, a showerhead according to the present disclosure comprises a weld joint between the central upper portion and the stem portion. In other words, in some examples, the central upper portion and stem portion are formed from different pieces of starting material (e.g., different blocks of aluminum) and then welded together. This can reduce the material cost of manufacturing the showerheads. In some examples, the weld joint between the central upper portion and the stem portion comprises a rotary friction weld (RFW) joint. Rotary friction welding is a solid-state joining process that fuses two materials together through the application of heat and pressure. In this technique, one of the workpieces is rotated at a high speed while the other remains stationary, causing friction and generating heat at the interface. The advantages of rotary friction welding include its ability to create strong, high-quality bonds between dissimilar materials, efficient energy usage, and the absence of consumables like filler metals or adhesives, making it an environmentally friendly and cost-effective welding technique.

[0077] FIG. 4 schematically represents an example showerhead backplate 400. As shown, showerhead backplate 400 comprises a central upper portion 402 and a stem portion 404. The showerhead backplate also comprises an RFW joint 406 attaching the central upper portion to the stem portion. It will be understood that the specific sizes and appearances of the backplate and stem portions 402 and 404 and RFW joint 406 of backplate 400 are non-limiting and presented only as one example.

[0078] As discussed above, showerheads according to the present disclosure comprise a faceplate having a plurality of outlet holes to emit processing chemicals from a plenum into an external environment. In some examples, it can be beneficial for a plenum-distal surface of the faceplate – e.g., a surface of the faceplate that faces the substrate – to have a concave profile. In other words, the "plenum-distal" surface of the faceplate refers to a showerhead surface that faces a substrate support when installed within a substrate processing tool. As mentioned above, thermal expansion of the faceplate during a heating cycle can result in bowing of the faceplate away from the plenum. This may geometrically deform the space between the faceplate and substrate, altering gas and/or plasma dynamics of any process chemicals emitted by the showerhead toward the substrate. As such, in some examples, a showerhead according to the present disclosure is manufactured to form the faceplate such that the plenum-

distal, substrate-facing surface of the faceplate has a controlled concavity. This can result in a more uniform distribution of processing chemicals even as the faceplate thermally expands.

[0079] This is schematically illustrated with respect to FIG. 5, showing a partial view of an example showerhead 500 according to the present disclosure. Showerhead 500 comprises a faceplate 502 and a backplate 504. A dashed line is used to indicate a profile 506 of the plenum-distal surface of the faceplate, which faces toward the substrate support when the showerhead is installed in a processing tool. The dashed line intersects a center of the plenum-distal surface of the faceplate, which is the point at which the concavity depth of faceplate is highest. In other words, the "concavity depth" refers to a distance between a point along the edge of the plenum-distal surface of the faceplate (which is relatively closer to the substrate), and a point at the center of the plenum-distal surface of the faceplate (which is relatively further from the substrate). FIG. 5 indicates the concavity depth 508 of faceplate 502. In some examples, the concavity depth is within a range of 0.001 inch to 0.05 inch, including the endpoints. It will be understood that the depiction of showerhead 500 in FIG. 5, and in particular the depiction of the concave profile 506, is simplified, schematic in nature, and not drawn to scale.

[0080] In other examples, other concavity depths can be used, depending on the specific processing environments in which the showerhead will be used. For instance, in some examples, the showerhead may be manufactured such that the faceplate has a profile with a controlled convexity rather than a controlled concavity – e.g., a plenum-distal surface of the faceplate has a convex profile. In some examples, a showerhead according to the present disclosure is manufactured such that the faceplate has a profile with a controlled concavity, although the target concavity depth is zero. In other words, in some examples, a showerhead has a target faceplate profile that is flat, with a predefined degree of tolerance for concavity or convexity. In one example, a showerhead according to the present disclosure comprises a faceplate with a concavity depth in a range between -0.003 inch and 0.003 inch including the endpoints – e.g., a slight convex profile to a slight concave profile.

[0081] FIG. 6 illustrates an example method 600 for assembling a showerhead for a substrate processing tool according to the present disclosure. Steps of method 600 may be implemented through any suitable distribution of manual and/or automated labor. In some examples, steps of method 600 are performed by, or are otherwise

facilitated by, one or more computers executing software, firmware, and/or hardware-encoded instructions.

[0082] At 602, method 600 includes inserting a plurality of posts of a faceplate into a plurality of post access holes of a backplate to define a plenum between the faceplate and the backplate. As mentioned above, when inserted, each post extends from the faceplate into a corresponding post access hole in the backplate, and a post shoulder of each post is recessed within the backplate relative to a plenum-facing surface of the backplate. Each post has a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of the corresponding post access hole into which the post extends.

[0083] At 604, method 600 includes welding each of the plurality of posts to the backplate within each post access hole. As mentioned above, in some examples, this is done through electron beam welding, although other suitable welding techniques may alternatively or additionally be used (e.g., friction-stir welding, tungsten arc welding). In other words, once the posts are inserted into the post access holes, an electron beam (or other suitable welding technique) can be applied to each post access hole to fuse the posts to the backplates, and thereby connect the faceplate to the backplate.

[0084] The disclosed example showerheads comprise structural features including, for example, unique post designs and controlled faceplate concavity that can address long-felt needs in the semiconductor processing industry. For a given process to work, the showerhead must be able to tolerate the required processing conditions. With advancements in wafer fabrication technology, some processes are now requiring relatively more extreme operating conditions than past processes. For example, as mentioned above, certain recipes may require processing conditions that would pose a particularly high risk of post fracture. When a post cracks, the showerhead is destroyed. Thus, there has been a need to develop a showerhead that can endure more extreme operating conditions for a longer period of time.

[0085] The disclosed post designs (e.g., post length, post diameter, recessed post shoulder) can improve the resilience of the showerhead to extreme temperatures experienced during some substrate processing recipes. Recessing the post shoulders within the backplates enables each post to have a recessed segment with a smaller post diameter than its corresponding post access hole. This, in tandem with the relatively longer overall length of each post between the faceplate and post shoulder, can provide each post with more freedom to flex, reducing strain on the posts and reducing

incidence of post cracking and fracture. Use of a faceplate with a controlled concave profile can beneficially provide more control over how the distribution of process chemicals is affected by thermal expansion of the faceplate during substrate processing. Notably, in some examples and under some processing conditions, a controlled concavity depth in a range of 0.015 inch to 0.025 inch, inclusive of the endpoints, can improve the uniformity of the distribution of processing chemicals over the substrate as the faceplate expands, as compared to a different showerhead with a flat or convex faceplate.

[0086] It will be understood that the configurations and/or approaches described herein are exemplary in nature, and that these specific examples are not to be considered in a limiting sense, because numerous variations are possible. The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

[0087] The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

CLAIMS:

1. A showerhead for a substrate processing tool, the showerhead comprising:

a faceplate comprising a plurality of outlet holes;

a backplate coupled to the faceplate, the backplate comprising a plurality of post access holes;

a plenum between the faceplate and backplate; and

a plurality of posts connecting the faceplate and the backplate, each post of the plurality of posts extending from the faceplate into a corresponding post access hole in the backplate, each post comprising a post shoulder recessed within the backplate relative to a plenum-facing surface of the backplate, and each post having a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of a post accommodation portion of the corresponding post access hole into which the post extends.

2. The showerhead of claim 1, wherein a length of each post between the faceplate and the post shoulder is within a range of 0.25 inch to 0.75 inch.

3. The showerhead of claim 2, wherein a recessed length of each post between the plenum-facing surface of the backplate and the post shoulder is within a range of 0.1 inch to 0.50 inch.

4. The showerhead of claim 1, wherein the post diameter of each post is within a range of 0.1 inch to 0.3 inch.

5. The showerhead of claim 4, wherein a difference between the post diameter of each post and the hole diameter of the post accommodation portion of each post access hole is within a range of 0.001 inch to 0.05 inch.

6. The showerhead of claim 1, wherein each post is integral with the faceplate and welded to the backplate.

7. The showerhead of claim 1, wherein the backplate comprises a central upper portion welded to a stem portion, and wherein a weld joint between the central upper portion and the stem portion comprises a rotary friction weld (RFW) joint.

8. The showerhead of claim 1, wherein a rim weld joint between the backplate and the faceplate comprises a friction stir weld (FSW) joint.

9. The showerhead of claim 1, wherein an outlet hole of the plurality of outlet holes comprises a chamfered edge at a plenum-facing entrance to the outlet hole.

10. The showerhead of claim 1, wherein a substrate facing surface of the faceplate has a concave profile.

11. The showerhead of claim 1, wherein a substrate facing surface of the faceplate has a convex profile.

12. The showerhead of claim 1, wherein each post access hole includes a welding access portion having a larger diameter than the hole diameter of the post accommodation portion of the post access hole.

13. A substrate processing tool, comprising:

a processing chamber; and

a showerhead to emit processing chemicals into the processing chamber, the showerhead comprising:

a faceplate comprising a plurality of outlet holes;

a backplate coupled to the faceplate, the backplate comprising a plurality of post access holes;

a plenum between the faceplate and backplate; and

a plurality of posts connecting the faceplate and the backplate, each post of the plurality of posts extending from the faceplate into a corresponding post access hole in the backplate, each post comprising a post shoulder recessed within the backplate relative to a plenum-facing surface of the backplate, and each post having a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of a post accommodation portion of the corresponding post access hole into which the post extends.

14. The substrate processing tool of claim 13, wherein a length of each post between the faceplate and the post shoulder is within a range of 0.25 inch to 0.75 inch.

15. The substrate processing tool of claim 14, wherein a recessed length of each post between the plenum-facing surface of the backplate and the post shoulder is within a range of 0.1 inch to 0.35 inch.

16. The substrate processing tool of claim 13, wherein the post diameter of each post is within a range of 0.1 inch to 0.3 inch.

17. The substrate processing tool of claim 16, wherein a difference between the post diameter of each post and the hole diameter of the post accommodation portion of each post access hole is within a range of 0.001 inch to 0.05 inch.

18. The substrate processing tool of claim 17, wherein the backplate comprises a central upper portion welded to a stem portion, and wherein a weld joint between the central upper portion and the stem portion comprises a rotary friction weld (RFW) joint.

19. The substrate processing tool of claim 13, wherein a rim weld joint between the backplate and the faceplate comprises a friction stir weld (FSW) joint.

20. A method for assembling a showerhead for a substrate processing tool, the method comprising:

inserting a plurality of posts of a faceplate into a plurality of post access holes of a backplate to define a plenum between the faceplate and the backplate, such that each post extends from the faceplate into a corresponding post access hole in the backplate, and a post shoulder of each post is recessed within the backplate relative to a plenum-facing surface of the backplate, each post having a post having a post diameter between the faceplate and the post shoulder that is smaller than a hole diameter of a post accommodation portion of the corresponding post access hole into which the post extends; and

welding each of the plurality of posts to the backplate within each post access hole.