access hole can help to avoid a hollow cathode discharge from forming in an unplugged post access hole when a plasma is formed using the showerhead as an electrode. However, welding the plug into the post access hole also increases a manufacturing cost for the showerhead. In contrast, the disclosed examples can include a radiused top edge at an opening of a post access hole in a backplate of a showerhead. The radiused top edge can help to prevent the formation of hollow cathode discharges without the use of plugging. Omitting the post access hole plugs lowers manufacturing costs.

[0054] 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), or other substrate process. The processing tool 100 comprises a processing chamber 102 containing 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.

[0055] 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.

[0056] 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 substrate 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.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] FIG. 2 shows a perspective view of an example showerhead 200. FIG. 3 shows a sectional view of the showerhead 200. The showerhead 200 is an example of the showerhead 104 of FIG. 1. The showerhead 200 comprises a faceplate 202 and a backplate 204. Referring to the sectional view of FIG. 3, a plenum 206 is located between the faceplate 202 and the backplate 204. The faceplate 202 includes a plurality

thicker than 0.65 inch. For example, the outlet holes 208 are formed by drilling through the faceplate 202. The outlet holes 208 can have uniform narrow diameters that pose challenges when drilling through thicker materials. Further, as mentioned above, the showerhead 200 can have hundreds or thousands of outlet holes 208. Thus, drilling a large number of outlet holes 208 through a faceplate thicker than 0.65 inch can take more time and incur greater expenses than drilling the outlet holes 208 through a faceplate in the range of 0.25 and 0.65 inch. Thus, a faceplate with a thickness of between 0.45 and 0.65 inch can provide a suitable balance between manufacturability and heat transfer performance.

[0064] In some examples, the faceplate 202 and the backplate 204 can be joined at a welded joint 214 at a perimeter of the plenum 206 by friction stir welding. 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 perimeter joint between the faceplate and the backplate compared to melt-joining methods.

[0065] Continuing with FIG. 3, the showerhead 200 comprises a plurality of posts 220 that connect the faceplate 202 and the backplate 204. Two posts 220 are shown in sectional view in FIG. 3 The posts 220 can be formed integrally with the faceplate 202, and welded to the backplate 204. The backplate 204 includes a post access hole 222 for each post 220. Referring to FIG. 2, and as described in more detail below, the backplate 204 has a total of twenty-four post access holes 222, and the faceplate 202 has a corresponding twenty-four posts 220. The post access holes 222 allow the posts 220 to be welded to the backplate 204 during showerhead manufacturing. For example, electron beam welding can be used to weld the posts 222 by placing each posts 220 into a corresponding post access holes 222, and directing an electron beam into the post access hole 222 to fuse the post with the backplate. In some examples, the showerhead 200 may have 25 to 30 total posts. The additional posts would be placed in the radial range where the outermost set of posts are located. For certain operations it is not ideal to have too many posts because too many posts may

reduce the gas flow rate. No outlet hole can be placed under the posts; therefore, more posts could equate to less outlet holes.

[0066] As mentioned above, posts in showerheads can experience cyclic strain due to temperature and thermal expansion differentials between the faceplate and the backplate. Posts that are closer to a perimeter of the showerhead plenum can experience a greater degree of strain than posts closer to a center of the showerhead plenum. This is because the magnitude of thermal expansion mismatch is higher at the perimeter of the plenum than closer to the center of the plenum.

[0067] Thus, showerhead 200 positions an outermost set of posts 240 (illustrated by a dashed line boundary around the corresponding post access holes 222) between 45% and 65% of a distance from a radial center of the plenum 206 indicated by dashed line 242 (hereinafter referred to as the center 242 of the plenum 206) to a perimeter 244 of the plenum 206. The term "outermost set of posts" indicates a set of posts 220 closest to the perimeter 244 of the plenum 206. The showerhead 200 has no posts 220 positioned between 65% and 100% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206. Positioning the outermost set of posts 240 within the range of 45% to 65% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206 can provide sufficient resistance to thermal bowing of the faceplate 202 while avoiding unduly straining the posts 220. The use of a relatively thicker faceplate 202 (for example, greater than 0.35 inches and less than 1.0 inches thick) can further help to avoid excessive strain on the posts 220. This is because such a faceplate 202 can transfer more heat per unit from the faceplate 202 to the backplate 204 than a backplate 204 with a thickness of 0.35 inch or thinner. This can help reduce temperature and thermal expansion differentials between the faceplate 202 and the backplate 204 compared to the use of a thinner faceplate 202.

[0068] In some examples, the outermost set of posts 240 is positioned between 50% and 65% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206. Positioning the outermost posts at a distance of 50% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206 can provide more resistance to thermal deformation of the faceplate 202 than an outermost set of posts positioned a distance less than 50% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206. In further examples, the outermost set of posts 240 is positioned between 52 and 58% of the distance from the center 242 of the plenum 206 to the perimeter 244 of the plenum 206.

[0077] FIG. 5 illustrates specific example radial and angular locations of posts 220. The depicted radial and angular locations are examples of angular locations that can help to achieve suitably uniform gas flow within the plenum 220 of the showerhead 200. However, the specific angular locations shown are presented for the purpose of example and are not intended to be limiting. In other examples, one or more posts 220 each can have a radial location and/or an angular location other than those shown. Further, in other examples, a showerhead may have either fewer or more than 24 posts. Additionally, in other examples, a quadrant may have fewer or more than three posts in an outmost set of posts.

[0078] As mentioned above, post access holes in some showerheads are plugged during manufacturing after welding the posts of the showerhead faceplate to the backplate through the post access holes. Plugging a post access hole can help to avoid hollow cathode discharge forming in the post access hole during use of the showerhead as an electrode to form a plasma. The formation of such parasitic plasmas decrease a plasma power used for substrate processing. However, plugging the post access holes generally involves welding a plug into each post access hole. This increases the time and cost of manufacturing a showerhead. However, it has been found that the plugging of post access holes can be avoided by forming a radiused edge at the post access hole opening on the showerhead backplate. FIG. 6 shows a sectional view of a portion of showerhead 200, and illustrates a radiused edge 600 at an opening of a post access hole 222 to an outer surface of the backplate. The radiused edge can have any suitable radius of curvature. Examples include radii of curvature within a range of 0.05 inch to -0.25 inch. The stated range is inclusive of the range endpoints.

[0079] Referring next to FIG. 7, in some such examples, each post of a showerhead can comprise a radius where the post meets an inner surface plane of a faceplate. FIG. 7 shows a portion of shows an example showerhead 700 comprising a post 702 with a radius 704 where the post meets an inner surface plane of a faceplate 706. The radius 704 can help to distribute strain experienced by the post 702 over a larger area than where a post lacks the radius 704. FIG. 7 also shows a plurality of outlet holes 708 arranged around the post 702. Post 702 and radius 704 are arranged so that an ordinary pattern of outlet holes 708 across the faceplate 706 of the showerhead is not disturbed by the post 702 and radius 704.

[0080] As mentioned above, a showerhead can include a baffle positioned in a plenum of the showerhead. Processing gases entering the showerhead through a gas

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;

a plenum between the faceplate and backplate; and

a plurality of posts connecting the faceplate and the backplate, an outermost set of posts of the plurality of posts being positioned between 45% and 65% of a distance from a center of the plenum to a perimeter of the plenum and no posts being positioned between 65% and 100% of the distance from the center of the plenum to the perimeter of the plenum.

2. The showerhead of claim 1, wherein the outermost set of posts of the plurality of posts is positioned between 50 and 65% of the distance from the center of the plenum to the perimeter of the plenum.

3. The showerhead of claim 1, wherein the outermost set of posts of the plurality of posts is positioned between 52 and 58% of the distance from the center of the plenum to the perimeter of the plenum, and wherein no posts are positioned between 58% and 100% of the distance from the center of the plenum to the perimeter of the plenum.

4. The showerhead of claim 3, wherein the plurality of posts are arranged such that any radial line extending from the center of the plenum to the perimeter of the plenum intersects a maximum of one post.

5. The showerhead of claim 1, wherein the plurality of posts are arranged such that any radial line extending from the center of the plenum to the perimeter of the plenum intersects a maximum of one post.

6. The showerhead of claim 1, wherein the plurality of posts comprises 20 or more posts.

7. The showerhead of claim 1, wherein the faceplate has a thickness greater than 0.35 inch and equal to or less than 1 inch.

8. The showerhead of claim 7, wherein the faceplate has a thickness within a range of 0.45 inch to 0.65 inch.

9. The showerhead of claim 1, wherein the backplate comprises a post access hole for each post, each post access hole comprising a radiused edge at an opening of the post access hole to an outer surface of the backplate.

10. The showerhead of claim 1, wherein each post is integral with the faceplate and welded to the backplate, and wherein each post comprises a radius where the post meets an inner surface plane of the faceplate.

11. The showerhead of claim 1, wherein the outermost set of posts is arranged in a circular pattern with at least three posts per each quadrant of the circular pattern, a first post being spaced from a second post of the three posts by a first angular distance along the circular pattern, and the second post being spaced from a third post by a second angular distance along the circular pattern, the first angular distance being shorter than the second angular distance.

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

a faceplate comprising a plurality of outlet holes;

a backplate coupled to the faceplate;

a plenum between the faceplate and backplate;

a plurality of posts connecting the faceplate and the backplate; and

a plurality of post access holes formed in the backplate, each post access hole comprising a radiused edge at an opening of the post access hole to an outer surface of the backplate.

13. The showerhead of claim 12, wherein a radius of curvature of the radiused edge is within a range of 0.05 inch to 0.25 inch.

14. The showerhead of claim 12, wherein an outermost set of posts of the plurality of posts is positioned between 52 and 58% of a distance from a center of the plenum

to a perimeter of the plenum, and wherein no posts are positioned between 58% and 100% of the distance from the center of the plenum to the perimeter of the plenum.

15. The showerhead of claim 12, wherein the plurality of posts are arranged such that any radial line extending from the center of the plenum to a perimeter of the plenum intersects a maximum of one post.

16. The showerhead of claim 12, wherein the plurality of posts comprises 20 or more posts.

17. The showerhead of claim 12, wherein the faceplate has a thickness greater than 0.45 inch and equal to or less than 0.55 inch.

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

a faceplate comprising a plurality of outlet holes;

a backplate coupled to the faceplate;

a plenum between the faceplate and backplate; and

a plurality of posts connecting the faceplate and the backplate, an outermost set of posts of the plurality of posts being arranged in a circular pattern with at least three posts per each quadrant of the circle pattern, a first post being spaced from a second post of the three posts by a first angular distance along the circular pattern, and the second post being spaced from a third post by a second angular distance along the circular pattern, the first angular distance being shorter than the second angular distance.

19. The showerhead of claim 18, wherein the outermost set of posts of the plurality of posts is positioned between 52 and 58% of a distance from a center of the plenum to a perimeter of the plenum, and wherein and no posts are positioned between 58% and 100% of the distance from the center of the plenum to the perimeter of the plenum.

20. The showerhead of claim 18, wherein the backplate comprises a post access hole for each post, each post access hole comprising a radiused edge at an opening of the post access hole to an outer surface of the backplate.