

Claims

1. A showerhead for delivering process gas to a plasma generation region within a substrate processing system, comprising:

a faceplate having a bottom side and a top side, the bottom side of the faceplate facing the plasma generation region during operation of the substrate processing system, the top side of the faceplate facing one or more plenums into which one or more process gases are supplied during operation of the substrate processing system, the faceplate having an overall thickness as measured between the bottom side and the top side of the faceplate,

the faceplate including apertures formed through the bottom side of the faceplate, the faceplate including openings formed through the top side of the faceplate, each of the apertures formed to extend through a portion of the overall thickness of the faceplate to intersect with at least one of the openings to form a corresponding flow path for process gas through the faceplate,

each of the apertures having a cross-section oriented parallel with the bottom side of the faceplate, the cross-section of each of the apertures having a hollow cathode discharge suppression dimension in at least one direction,

each of the openings having a cross-section oriented parallel with the top side of the faceplate, each of the openings having a smallest cross-sectional dimension that is greater than the hollow cathode discharge suppression dimension,

wherein the hollow cathode discharge suppression dimension is within a range extending from about 0.005 inch to about 0.04 inch.

2. The showerhead as recited in claim 1, wherein each of the openings is formed to extend through at least 50% of the overall thickness of the faceplate.

3. The showerhead as recited in claim 1, wherein each of the openings is formed to extend through at least 90% of the overall thickness of the faceplate.

4. The showerhead as recited in claim 1, wherein the portion of the overall thickness of the faceplate is within a range extending from about 0.001 inch to about 0.03 inch.

~~5. The showerhead as recited in claim 1, wherein the hollow cathode discharge suppression dimension is within a range extending from about 0.005 inch to about 0.04 inch.~~

~~6. The showerhead as recited in claim 1, wherein the hollow cathode discharge suppression dimension is within a range extending from about 0.008 inch to about 0.018 inch.~~

5. A showerhead for delivering process gas to a plasma generation region within a substrate processing system, comprising:

a faceplate having a bottom side and a top side, the bottom side of the faceplate facing

the plasma generation region during operation of the substrate processing system, the top side of the faceplate facing one or more plenums into which one or more process gases are supplied during operation of the substrate processing system, the faceplate having an overall thickness as measured between the bottom side and the top side of the faceplate,

5 the faceplate including apertures formed through the bottom side of the faceplate, the faceplate including openings formed through the top side of the faceplate, each of the apertures formed to extend through a portion of the overall thickness of the faceplate to intersect with at least one of the openings to form a corresponding flow path for process gas through the faceplate,

each of the apertures having a cross-section oriented parallel with the bottom side of the faceplate, the cross-section of each of the apertures having a hollow cathode discharge suppression dimension in at least one direction,

each of the openings having a cross-section oriented parallel with the top side of the faceplate, each of the openings having a smallest cross-sectional dimension that is greater than the hollow cathode discharge suppression dimension,

15 wherein the hollow cathode discharge suppression dimension is within a range extending from about 0.008 inch to about 0.018 inch.

76. The showerhead as recited in claim 1, wherein the openings are formed as circular holes.

20 87. The showerhead as recited in claim 76, wherein the openings are arranged in either a hexagonal lattice array, ~~a square lattice array, a rectangular lattice array, a rhombic lattice array, a parallelogrammic lattice array, a Vogel pattern, or a customized pattern.~~

98. The showerhead as recited in claim 87, wherein the apertures are formed as slots that extend through the bottom side of the faceplate.

25 109. The showerhead as recited in claim 91, wherein each of the apertures is formed as a portion of any one of a plurality of slots, each slot of the plurality of slots extends~~extending~~ in a continuous manner across the bottom side of the faceplate, the plurality of slots oriented parallel to each other.

110. The showerhead as recited in claim 9, wherein the slots are separately formed at

locations of the openings.

1211. The showerhead as recited in claim 1110, wherein each of the slots has a substantially rectangular cross-sectional shape in an orientation parallel with the bottom side of the faceplate, the slots oriented either parallel with respect to each other, or in an ordered manner with respect to each other, or in a random manner with respect to each other.

1312. The showerhead as recited in claim 1110, wherein each of the slots has a curved cross-sectional shape in an orientation parallel with the bottom side of the faceplate, wherein each opening intersects a separate pair of slots within the faceplate.

1413. The showerhead as recited in claim 1312, wherein the curved cross-sectional shape is either a C-shape or a bracket shape.

1514. The showerhead as recited in claim 87, wherein each of the apertures has a circular cross-sectional shape in an orientation parallel with the bottom side of the faceplate.

1615. The showerhead as recited in claim 76, wherein the openings are arranged in a Vogel pattern, and the apertures are formed as grooves that extend through the bottom side of the faceplate, the grooves formed in a Vogel pattern to intersect the openings.

1716. The showerhead as recited in claim 1, wherein the openings are formed as a first set of grooves that extend through the top side of the faceplate, and the apertures are formed as a second set of grooves that extend through the bottom side of the faceplate, the first set of grooves formed in a first Vogel pattern, the second set of grooves formed in a second Vogel pattern, the first and second Vogel patterns traversing in reverse direction with respect to each other.

1817. The showerhead as recited in claim 1, wherein the openings are formed as a first set of grooves that extend through the top side of the faceplate, and the apertures are formed as a second set of grooves that extend through the bottom side of the faceplate, the first set of grooves formed in a radial-spoke pattern, the second set of grooves also formed in the radial-spoke pattern to intersect with the first set of grooves.

1918. The showerhead as recited in claim 1, wherein the openings are formed as a first set of grooves that extend through the top side of the faceplate, and the apertures are formed as a second set of grooves that extend through the bottom side of the faceplate, the first set of grooves formed in a radial-spoke pattern, the second set of grooves formed in a concentric-circular pattern to intersect with the first set of grooves.

2019. A faceplate for a showerhead for delivering process gas to a plasma generation region within a substrate processing system, comprising:

a disc having a bottom side and a top side, the bottom side of the disc facing the plasma

generation region during operation of the substrate processing system, the top side of the disc facing one or more plenums into which one or more process gases are supplied during operation of the substrate processing system, the disc having an overall thickness as measured between the bottom side and the top side of the disc,

5 the disc including apertures formed through the bottom side of the disc, the disc including openings formed through the top side of the disc, each of the apertures formed to extend through a portion of the overall thickness of the disc to intersect with at least one of the openings to form a corresponding flow path for process gas through the disc,

 each of the apertures having a cross-section oriented parallel with the bottom side of the
10 disc, the cross-section of each of the apertures having a hollow cathode discharge suppression dimension in at least one direction,

 each of the openings having a cross-section oriented parallel with the top side of the disc, each of the openings having a smallest cross-sectional dimension that is greater than the hollow cathode discharge suppression dimension,

15 wherein the hollow cathode discharge suppression dimension is within a range extending from about 0.005 inch to about 0.04 inch.

20. The showerhead as recited in claim 6, wherein the openings are arranged in either a square lattice array, a rectangular lattice array, a rhombic lattice array, a parallelogrammic lattice array, a Vogel pattern, or a customized pattern.

20 ~~21. — A method for manufacturing a faceplate of a showerhead for delivering process gas to a plasma generation region within a substrate processing system, comprising:~~

~~— providing a disc having a bottom side and a top side, the bottom side of the disc to face the plasma generation region during operation of the substrate processing system, the top side of the disc to face one or more plenums into which one or more process gases are supplied during operation of the substrate processing system, the disc having an overall thickness as measured between the bottom side and the top side of the disc;~~

25 ~~— forming apertures through the bottom side of the disc, each of the apertures having a cross-section oriented parallel with the bottom side of the disc, the cross-section of each of the apertures formed to have a hollow cathode discharge suppression dimension in at least one direction; and~~

30 ~~— forming openings through the top side of the disc to intersect with at least one of the apertures within the disc to form a corresponding flow path for process gas through the disc, each of the openings having a cross-section oriented parallel with the top side of the disc, each of the openings formed to have a smallest cross-sectional dimension that is greater than the~~

hollow cathode discharge suppression dimension.