

CLAIMS

What is claimed is:

1. A first edge ring for a substrate support, the first edge ring comprising:
an annular-shaped body sized and shaped to surround an upper portion of the
5 substrate support, wherein the annular-shaped body defines
an upper surface,
a lower surface,
a radially inner surface, and
a radially outer surface; and
10 one or more lift pin receiving elements disposed along the lower surface of the
annular-shaped body and sized and shaped to receive and provide kinematic coupling
with top ends respectively of three or more lift pins,
wherein the one or more lift pin receiving elements include at least one groove
shaped to contact a corresponding one of the three or more lift pins at only two points
15 at a time.
2. The first edge ring of claim 1, comprising three lift pin receiving elements
disposed along the lower surface of the annular-shaped body.
3. The first edge ring of claim 1, wherein:
the annular-shaped body comprises an inner diameter; and
20 the inner diameter is greater than an outer diameter of a top portion of the
substrate support.
4. The first edge ring of claim 1, wherein the annular-shaped body is formed at
least partially of a non-volatile material.
5. The first edge ring of claim 1, wherein the one or more lift pin receiving elements
25 include at least one groove.
6. The first edge ring of claim 1, wherein the one or more lift pin receiving elements
include at least one 'V'-shaped groove.

7. The first edge ring of claim 6, wherein the at least one “V”-shaped groove comprises walls at 60-120° relative to each other.
8. The first edge ring of claim 6, wherein the at least one “V”-shaped groove comprises walls at 45° relative to each other.
- 5 9. The first edge ring of claim 1, wherein:
the one or more lift pin receiving elements comprise at least one groove with a rounded vertex portion; and
the rounded vertex portion has a radius between 0.4571 mm and 0.889 mm (.018” and .035”).
- 10 10. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include at least one of a rounded groove, a groove with half conically shaped ends, or a groove with quarter hemi-spherically shaped ends.
11. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include at least one divot.
- 15 12. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include chamfered side walls.
13. The first edge ring of claim 1, wherein at least one of the one or more lift pin receiving elements includes a beveled portion to guide one of the three or more lift pins into the at least one of the one or more lift pin receiving elements.
- 20 14. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include:
a first lift receiving element with a groove; and
a second lift pin receiving element with a divot.
15. The first edge ring of claim 1, wherein the one or more lift pin receiving elements
25 include at least one groove with parallel side walls and a flat or rounded top wall.

16. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include only three lift pin receiving elements.
17. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include at least one notch disposed at a bottom periphery of the annular-shaped body.
- 5 18. The first edge ring of claim 17, wherein the at least one notch includes:
a 'V'-shaped groove and a half conically shaped end; or
a quarter hemi-spherically shaped end.
19. The first edge ring of claim 1, wherein the one or more lift pin receiving elements are spaced 120° apart relative to a center of the annular-shaped body.
- 10 20. The first edge ring of claim 1, wherein the one or more lift pin receiving elements include at least one groove shaped to contact a corresponding one of the three or more lift pins at only two points at a time.
21. The first edge ring of claim 20, wherein the at least one groove is shaped such that the corresponding one of the three or more lift pins does not contact an uppermost
15 portion or a vertex portion of the at least one groove.
22. An edge ring system comprising:
the first edge ring of claim 1; and
the three or more lift pins.
23. The system of claim 22, wherein:
20 the one or more lift pin receiving elements comprise at least one groove; and
a ratio of a depth of the at least one groove and a diameter of a corresponding one of the three or more lift pins is 1:1.
24. The system of claim 22, wherein:
25 the one or more lift pin receiving elements comprise at least one groove; and
a ratio between a depth of the at least one groove and a diameter of a corresponding one of the three or more lift pins is between 10:1 and 1:8.

25. The system of claim 22, wherein:

the one or more lift pin receiving elements comprise at least one groove;

the at least one groove includes side walls; and

a ratio between ~~the~~ a width of the at least one groove and a diameter of a

5 corresponding one of the three or more lift pins is between 20:1 and 1:4.

26. The system of claim 22, wherein:

the one or more lift pin receiving elements comprise at least one groove; and

a ratio between a depth a corresponding one of the three or more lift pins is
disposed into the at least one groove and a depth of the at least one groove is between

10 10:1 and 1:8.

27. The system of claim 22 wherein each of the three or more lift pins is shaped to
contact two points on surfaces of a corresponding one of the one or more lift pin
receiving elements at a time and not contact a top surface or vertex portion of the
corresponding one of the one or more lift pin receiving elements.

15 28. The system of claim 22, wherein the three or more lift pins are formed at least
partially of a volatile material.

29. The system of claim 22, further comprising:

at least one actuator for moving the three or more lift pins; and

a controller configured to control operation of the at least one actuator.

20 30. ~~The~~An edge ring system of claim 22, further comprising:

three or more lift pins;

a first edge ring for a substrate support, the first edge ring comprising

an annular-shaped body sized and shaped to surround an upper portion
of the substrate support, wherein the annular-shaped body defines

25 an upper surface,

a lower surface,

a radially inner surface, and

a radially outer surface; and

one or more lift pin receiving elements disposed along the lower surface of the annular-shaped body and sized and shaped to receive and provide kinematic coupling with top ends respectively of three or more lift pins;

a second edge ring; and

5 at least one stabilizing element disposed in at least one pocket of the annular-shaped body and applying pressure on the second edge ring.

31. The system of claim 22, further comprising:

a second edge ring; and

a third edge ring,

10 wherein the first edge ring, the second edge ring and the third edge ring are arranged in a stack.

32. The system of claim 31, wherein the second edge ring and the third edge ring are each formed at least partially of a volatile material.

33. ~~The~~An edge ring system of claim 22, further comprising

15 three or more lift pins;

a first edge ring for a substrate support, the first edge ring comprising

an annular-shaped body sized and shaped to surround an upper portion of the substrate support, wherein the annular-shaped body defines

an upper surface,

20 a lower surface,

a radially inner surface, and

a radially outer surface; and

one or more lift pin receiving elements disposed along the lower surface of the annular-shaped body and sized and shaped to receive and provide kinematic coupling with top ends respectively of three or more lift pins; and

25 a second edge ring comprising a first top surface and a second top surface, wherein:

30 the first top surface is disposed adjacent a top surface of the substrate support and below a periphery of a substrate, wherein the first top surface is disposed (i) at a level higher than a level of a bottom surface of the first edge ring, and (ii) radially inside the first edge ring;

the second top surface is disposed below a portion of the first edge ring, the second top surface is disposed at a level lower than the level of the bottom surface of the first edge ring; and

an instep from the first top surface to the second top surface.

- 5 34. The system of claim 33, wherein the second edge ring is formed at least partially of a volatile material.

~~35.— A collapsible edge ring assembly for a substrate support, the collapsible edge ring assembly comprising:~~

10 ~~a plurality of edge rings arranged in a stack, wherein at least one of the plurality of edge rings is shaped and sized to surround an upper portion of the substrate support, and wherein the plurality of edge rings comprise a top edge ring and at least one intermediate edge ring; and~~

15 ~~three or more ring alignment and spacing elements contacting each of the plurality of edge rings and configured to maintain radial alignment and vertical spacing of the plurality of edge rings, wherein the three or more ring alignment and spacing elements are configured to lift the at least one intermediate edge ring while the top edge ring is lifted.~~

20 ~~36.— The collapsible edge ring assembly of claim 35, wherein the three or more ring alignment and spacing elements are sized to define spacing between adjacent ones of the plurality of edge rings during vertical displacement of the plurality of edge rings.~~

~~37.— The collapsible edge ring assembly of claim 36, wherein the top edge ring comprises three or more lift pin receiving elements sized and shaped to receive top ends of three or more lift pins.~~

25 ~~38.— The collapsible edge ring assembly of claim 37, wherein the at least one intermediate edge ring comprises holes for passage of the three or more lift pins.~~

~~39.— The collapsible edge ring assembly of claim 35, wherein the plurality of edge rings have:~~

~~a fully retracted state, where the plurality of edge rings are in contact with each other; and~~

~~an expanded state, where the plurality of edge rings are spaced apart from each other.~~

40. ~~The collapsible edge ring assembly of claim 39, wherein a plasma sheath tilt angle associated with a periphery of the top edge ring is smaller when the plurality of edge rings are in the fully retracted state than when in the expanded state.~~

41. ~~The collapsible edge ring assembly of claim 35, wherein the three or more ring alignment and spacing elements comprise only three ring alignment and spacing elements spaced 120° apart from each other.~~

42. ~~The collapsible edge ring assembly of claim 35, wherein:
at least one of the three or more ring alignment and spacing elements is tiered to have a plurality of levels; and
each of the plurality of levels lifts a respective one of the plurality of edge rings.~~

43. ~~The collapsible edge ring assembly of claim 42, wherein:
the plurality of levels have respective steps; and
heights of the respective steps are equal in size.~~

44. ~~The collapsible edge ring assembly of claim 42, wherein:
the plurality of levels comprise a first level, a second level and a third level;
the first level is disposed above the second level;
the second level is disposed above the third level;
the third level is wider than the second level; and
the second level is wider than the first level.~~

45. ~~The collapsible edge ring assembly of claim 35, wherein at least one of the three or more ring alignment and spacing elements comprises a plurality of interlocking sections.~~

46. ~~The collapsible edge ring assembly of claim 35, wherein at least one of the three or more ring alignment and spacing elements comprises a plurality of telescopic sections.~~

47. ~~The collapsible edge ring assembly of claim 35, wherein:
at least one of the three or more ring alignment and spacing elements comprises
a main member and a plurality of fingers; and
the plurality of fingers extend radially inward from the main member and lift
respective ones of the plurality of edge rings.~~

48. ~~The collapsible edge ring assembly of claim 47, wherein the plurality of fingers
are configured to interlock into or be disposed in notches of corresponding ones of the
plurality of edge rings.~~

49. ~~The collapsible edge ring assembly of claim 35, wherein:
the at least one intermediate edge ring comprising a first intermediate edge ring
and a second intermediate edge ring;
the first intermediate edge ring has a first thickness; and
the second intermediate edge ring has a second thickness, the second thickness
is greater than the first thickness.~~

50. ~~The collapsible edge ring assembly of claim 35, wherein:
the three or more ring alignment and spacing elements are implemented as
stepped lift pins; and
the stepped lift pins are configured to lift the plurality of edge rings.~~

51. ~~The collapsible edge ring assembly of claim 35, further comprising a first set of
lift pins, wherein:
the three or more ring alignment and spacing elements are implemented as a
second set of lift pins; and
the first set of lift pins are configured to lift the top edge ring.~~

52. ~~The collapsible edge ring assembly of claim 35, wherein the plurality of edge
rings are each formed at least partially of a non-volatile material.~~

53. ~~The collapsible edge ring assembly of claim 35, wherein the three or more ring
alignment and spacing elements are each formed at least partially of a volatile material.~~

54. ~~A system comprising:~~

~~the collapsible edge ring assembly of claim 35; and
a plurality of lift pins that extend through the at least one of the plurality of edge
rings and into the three or more lift pin receiving elements.~~

~~55. The system of claim 54, further comprising:~~

5 ~~at least one actuator for moving the plurality of lift pins; and
a controller configured to control operation of the at least one actuator.~~

~~56. A collapsible edge ring assembly for a substrate support, the collapsible edge
ring assembly comprising:~~

10 ~~a plurality of edge rings arranged in a stack, wherein at least one of the plurality
of edge rings is shaped and sized to surround an upper portion of the substrate
support, and wherein the plurality of edge rings comprise a top edge ring and at least
one intermediate edge ring; and~~

15 ~~a stepped outer edge ring comprising a plurality of levels, wherein the plurality of
edge rings are disposed respectively on the plurality of levels, wherein the stepped
outer edge ring is configured to maintain radial alignment and vertical spacing of the
plurality of edge rings, and wherein the stepped outer edge ring is configured to lift the
at least one intermediate edge ring while the top edge ring is lifted.~~

~~57. The collapsible edge ring assembly of claim 56, wherein:~~

20 ~~the plurality of levels have respective steps; and
heights of the respective steps are equal in size.~~

~~58. The collapsible edge ring assembly of claim 56, wherein:~~

25 ~~the plurality of levels comprise a first level, a second level and a third level;
the first level is disposed above the second level;
the second level is disposed above the third level;
the third level has an inner diameter that is greater than an inner diameter of the
second level; and
the inner diameter of the second level is greater than an inner diameter of the
first level.~~

30 ~~59. The collapsible edge ring assembly of claim 56, wherein the stepped outer edge
ring is formed at least partially of a non-volatile material.~~

60.—~~The collapsible edge ring assembly of claim 56, wherein the stepped outer edge ring has a flange that extends radially inward to be disposed on a plurality of lift pins.~~

61.—~~A system comprising:~~

~~the collapsible edge ring assembly of claim 60; and~~

~~the plurality of lift pins.~~

62.—~~The system of claim 61, further comprising a stabilizing edge ring disposed between the plurality of edge rings and the flange.~~

63.—~~The system of claim 62, further comprising the substrate support, wherein the stabilizing ring is disposed between the substrate support and the plurality of edge rings.~~

64.—~~The system of claim 62, wherein:~~

~~the stabilizing edge ring comprises a first top surface and a second top surface, wherein:~~

~~the first top surface is disposed adjacent a top surface of the substrate support and below a periphery of a substrate, wherein the first top surface is disposed (i) at a level higher than a level of a bottom surface of the first edge ring, and (ii) radially inside the first edge ring;~~

~~the second top surface is disposed below a portion of the first edge ring, the second top surface is disposed at a level lower than the level of the bottom surface of the first edge ring; and~~

~~an instep from the first top surface to the second top surface.~~