CLAIMS

1. An electrical purification apparatus comprising:

a plurality of alternating ion depleting compartments and ion concentrating compartments defined by a plurality of ion exchange membranes, each of the plurality of ion depleting compartments and ion concentrating compartments comprising

a spacer comprising a body and a cap, the cap having a thickness of less than about 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold, and the spacer constructed and arranged to provide a product water resistivity of between about 10 megohm-cm to about 18 megohm-cm over a feed conductivity equivalent of about 5 μS/cm to about 100 μS/cm.

2. The electrical purification apparatus of claim 1, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

3. The electrical purification apparatus of claim 2, further comprising a first modified spacer positioned at a first end of the electrical purification apparatus, and a second modified spacer positioned at a second end of the electrical purification apparatus.

4. The electrical purification apparatus of claim 3, further comprising a first endblock positioned adjacent the first modified spacer, and a second endblock positioned adjacent the second modified spacer, wherein the first endblock and the second endblock have identical geometries.

5. The electrical purification apparatus of claim 1, wherein a thickness of the spacer is in a range of about 2 mm to about 4 mm.

6. The electrical purification apparatus of claim 1, wherein the spacer is constructed and arranged to provide uniform fluid flow through each of the plurality of ion depleting and ion concentrating compartments.

7. The electrical purification apparatus of claim 6, wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

8. An electrical purification apparatus comprising:

a plurality of alternating ion depleting compartments and ion concentrating compartments defined by a plurality of ion exchange membranes, each of the plurality of ion depleting compartments and ion concentrating compartments comprising

a spacer comprising a body and a cap, the cap having a thickness of 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold to provide uniform fluid flow through each of the compartments.

9. The electrical purification apparatus of claim 8, wherein the manifold comprises channels to direct the fluid to the compartment.

10. The electrical purification apparatus of claim 9, wherein the cap comprises ridges and grooves that provide for the channels in the manifold when mated with the body.

11. The electrical purification apparatus of claim 8, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

12. The electrical purification apparatus of claim 11, further comprising a first modified spacer positioned at a first end of the electrical purification apparatus, and a second modified spacer positioned at a second end of the electrical purification apparatus.

13. The electrical purification apparatus of claim 12, further comprising a first endblock positioned adjacent the first modfied spacer, and a second endblock positioned adjacent the second modified spacer, wherein the first endblock and the second endblock have identical geometries.

14. The electrical purification apparatus of claim 8, wherein the spacer is constructed and arranged to provide a product water resistivity of between about 10 megohm-cm to about 18 megohm-cm over a feed conductivity equivalent of about 5 μS/cm to about 100 μS/cm.

15. The electrical purification apparatus of claim 8, wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

16. The electrical purification apparatus of claim 8, wherein a thickness of the spacer is in a range of about 2 mm to about 4 mm.

17. A system for providing ultrapure water comprising:

a source a water comprising a total dissolved solids of about 50 ppm to about 1000 ppm;

a single-pass reverse osmosis unit fluidly connected to the source of water;

a single-pass electrodeionization device fluidly connected to the single-pass reverse osmosis unit comprising a plurality of concentrating compartments and diluting compartments, each of the compartments having a thickness of less than about 4 mm, the device constructed and arranged to provide water comprising a total dissolved solids of about 5 ppb to about 100 ppb.

18. The system of claim 17, wherein each of the plurality of ion concentrating compartments and ion depleting compartments comprises a spacer comprising a body and a cap, the cap having a thickness of 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold to provide uniform fluid flow through each of the compartments.

19. The system of claim 18, wherein the manifold comprises channels to direct the fluid to the compartment.

20. The system of claim 19, wherein the cap comprises ridges and grooves that provide for the channels in the manifold when mated with the body.

21. The system of claim 17, further comprising a first modified spacer positioned at a first end of the electrodeionization device, and a second modified spacer positioned at a second end of the electrodeionization device.

22. The system of claim 17, further comprising a first endblock positioned adjacent the first modified spacer, and a second endblock positioned adjacent the second

modified spacer, wherein the first endblock and the second endblock have identical geometries.

23. The system of claim 17, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

24. The system of claim 18, wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

25. A method for providing ultrapure water comprising:

introducing a water comprising a feed conductivity equivalent of about 100 µS/cm to about 2000 µS/cm to a single-pass reverse osmosis unit to produce a filtrate comprising a conductivity equivalent of about 5 µS/cm to about 100 µS/cm;

introducing the filtrate into a single-pass electrodeionization device comprising a plurality of concentrating compartments and diluting compartments, each of the compartments having a thickness of less than about 4 mm, to provide a product water comprising a resistivity of about 5 megohm-cm to about 18 megohm-cm.

26. The method of claim 25, wherein each of the plurality of ion concentrating compartments and ion depleting compartments comprises a spacer comprising a body and a cap having a thickness of 1 mm, the cap comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold to provide uniform fluid flow through each of the compartments.

27. The method of claim 26, wherein introducing the filtrate into a single-pass electrodeionization device comprises directing fluid through a channel in the manifold.

28. The method of claim 26, wherein the cap comprises ridges and grooves that provide for the channel in the manifold when mated with the body.

29. The method of claim 26, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

30. The method of claim 26, wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

CLAIMS

1. An electrical purification apparatus comprising:

a plurality of alternating ion depleting compartments and ion concentrating compartments defined by a plurality of ion exchange membranes, each of the plurality of ion depleting compartments and ion concentrating compartments comprising

a spacer comprising a body and a cap, the cap having a thickness of less than about 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold, and the spacer constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer, and to provide a product water resistivity of between about 10 megohm-cm to about 18 megohm-cm over a feed conductivity equivalent of about 5 μS/cm to about 100 μS/cm.

2. The electrical purification apparatus of claim 1, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

3. The electrical purification apparatus of claim 2, further comprising a first modified spacer positioned at a first end of the electrical purification apparatus, and a second modified spacer positioned at a second end of the electrical purification apparatus.

4. The electrical purification apparatus of claim 3, further comprising a first endblock positioned adjacent the first modified spacer, and a second endblock positioned adjacent the second modified spacer, wherein the first endblock and the second endblock have identical geometries.

5. The electrical purification apparatus of claim 1, wherein a thickness of the spacer is in a range of about 2 mm to about 4 mm.

6. An electrical purification apparatus comprising:

a plurality of alternating ion depleting compartments and ion concentrating compartments defined by a plurality of ion exchange membranes, each of the plurality of ion depleting compartments and ion concentrating compartments comprising

a spacer comprising a body and a cap, the cap having a thickness of 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold to provide uniform fluid flow through each of the compartments, the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point

within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

7. The electrical purification apparatus of claim 6, wherein the manifold of each of the spacers comprises channels to direct the fluid to each of the compartments.

8. The electrical purification apparatus of claim 7, wherein the cap comprises ridges and grooves that provide for the channels in the manifold when mated with the body.

9. The electrical purification apparatus of claim 6, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

10. The electrical purification apparatus of claim 9, further comprising a first modified spacer positioned at a first end of the electrical purification apparatus, and a second modified spacer positioned at a second end of the electrical purification apparatus.

11. The electrical purification apparatus of claim 10, further comprising a first endblock positioned adjacent the first modified spacer, and a second endblock positioned adjacent the second modified spacer, wherein the first endblock and the second endblock have identical geometries.

12. The electrical purification apparatus of claim 6, wherein the spacer is constructed and arranged to provide a product water resistivity of between about 10 megohm-cm to about 18 megohm-cm over a feed conductivity equivalent of about 5 μS/cm to about 100 μS/cm.

13. The electrical purification apparatus of claim 6, wherein a thickness of the spacer is in a range of about 2 mm to about 4 mm.

14. A system for providing ultrapure water comprising:

a source a water comprising a total dissolved solids of about 50 ppm to about 1000 ppm;

a single-pass reverse osmosis unit fluidly connected to the source of water;

a single-pass electrodeionization device fluidly connected to the single-pass reverse osmosis unit comprising a plurality of concentrating compartments and diluting compartments, each of the compartments having a thickness of less than about 4 mm, the device constructed and arranged to provide water comprising a total dissolved solids of about 5 ppb to about 100 ppb,

wherein each of the plurality of ion concentrating compartments and ion depleting compartments comprises a spacer comprising a body and a cap, the cap having a thickness of 1 mm and comprising a first component that is mated with a second component on the body to provide a seal, the

cap and the body defining a manifold to provide uniform fluid flow through each of the compartments, and

wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

15. The system of claim 14, wherein the manifold comprises channels to direct the fluid to the compartment.

16. The system of claim 15, wherein the cap comprises ridges and grooves that provide for the channels in the manifold when mated with the body.

17. The system of claim 14, further comprising a first modified spacer positioned at a first end of the electrodeionization device, and a second modified spacer positioned at a second end of the electrodeionization device.

18. The system of claim 17, further comprising a first endblock positioned adjacent the first modified spacer, and a second endblock positioned adjacent the second modified spacer, wherein the first endblock and the second endblock have identical geometries.

19. The system of any one of claims 14 to 18, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.

20. A method for providing ultrapure water comprising:

introducing a water comprising a feed conductivity equivalent of about 100 μS/cm to about 2000 μS/cm to a single-pass reverse osmosis unit to produce a filtrate comprising a conductivity equivalent of about 5 μS/cm to about 100 μS/cm;

introducing the filtrate into a single-pass electrodeionization device comprising a plurality of concentrating compartments and diluting compartments, each of the compartments having a thickness of less than about 4 mm, to provide a product water comprising a resistivity of about 5 megohm-cm to about 18 megohm-cm,

wherein each of the plurality of ion concentrating compartments and ion depleting compartments comprises a spacer comprising a body and a cap having a thickness of 1 mm, the cap comprising a first component that is mated with a second component on the body to provide a seal, the cap and the body defining a manifold to provide uniform fluid flow through each of the compartments, and

wherein the spacer is constructed and arranged to provide a fluid flow velocity at a first point, a second point, and a third point within about 5 percent to about 10 percent of each other to provide the uniform fluid flow, the first point, the second point, and the third point running parallel to an edge of the spacer.

21. The method of claim 20, wherein introducing the filtrate into a single-pass electrodeionization device comprises directing fluid through a channel in the manifold.

22. The method of claim 21, wherein the cap comprises ridges and grooves that provide for the channel in the manifold when mated with the body.

23. The method of claim 20, 21 or 22, wherein the spacer comprises a first side having an uneven surface, and a second side having a flat surface.