CLAIMS

1. A dialysis fluid regeneration system, comprising:

a nanostructured photo-electrochemical anode;

a source of light configured to illuminate the photo-electrochemical anode; and

a cathode that is permeable to oxygen provided to a dialysis fluid and non-permeable to a liquid of the dialysis fluid, wherein the photo-electrochemical anode is configured to be in contact with the dialysis fluid, and configured to regenerate the dialysis fluid by converting urea in the dialysis fluid into CO_2, N_2 and H_2O through a photo-electrochemical reaction.

2. The dialysis fluid regeneration system of claim 1, wherein the dialysis fluid is a dialysate.

3. The dialysis fluid regeneration system of claim 1, wherein the dialysis fluid regeneration system is a kidney dialysis system.

4. The dialysis fluid regeneration system of claim 3, wherein the dialysis fluid regeneration system is a hemofiltration system, or a hemodialysis system, or a hemodiafiltration system.

5. The dialysis fluid regeneration system of claim 1, further comprising a source of electrical voltage operationally coupled to the anode and the photo-electrochemical anode and the cathode.

6. The dialysis fluid regeneration system of claim 5, wherein the source of electrical voltage is portable.

7. The dialysis fluid regeneration system of claim 1, wherein the dialysis fluid regeneration system is portable or wearable.

8. The dialysis fluid regeneration system of claim 1, wherein the dialysis fluid regeneration system is stationary.

9. The dialysis fluid regeneration system of claim 1, wherein the photo-electrochemical anode, the source of light, and the cathode that is permeable to the oxygen and nonpermeable to the liquid of the dialysis fluid are parts of one dialysis-fluid regeneration cell, and wherein the dialysis fluid regeneration system comprises a plurality of additional dialysis-fluid regeneration cells.

10. The dialysis fluid regeneration system of claim 1, wherein the cathode is an air-breathable cathode.

11. The dialysis fluid regeneration system of claim 10, wherein the cathode is a conductive cloth-based cathode or a conductive paper-based cathode.

12. The dialysis fluid regeneration system of claim 11, wherein the cloth-based cathode comprises a platinum-coated cloth.

13. The dialysis fluid regeneration system of claim 11, wherein the cathode is configured to electrochemically split water.

14. The dialysis fluid regeneration system of claim 1, wherein nanostructures of the photo-electrochemical anode are configured to generate photo-electrons or holes when exposed to light emitted by the source of light.

15. The dialysis fluid regeneration system of claim 1, wherein the source of light comprises an array of light emitting diodes (LEDs).

16. The dialysis fluid regeneration system of claim 15, wherein the LEDs are arranged in a two-dimensional (2D) array.

17. The dialysis fluid regeneration system of claim 15, wherein the LEDs generate an irradiance of less than 4 mW/cm^2 at a surface of the photo-electrochemical anode.

18. The dialysis fluid regeneration system of claim 15, wherein the LEDs emit light at 365 nm wavelength.

19. The dialysis fluid regeneration system of claim 1, wherein the source of light comprises a source of ultraviolet (UV) light.

20. The dialysis fluid regeneration system of claim 1, wherein the source of light comprises a source of visible light.

21. The dialysis fluid regeneration system of claim 14, wherein an incident photon to photoelectron efficiency is about 51%.

22. The dialysis fluid regeneration system of claim 1, wherein the nanostructured photo-electrochemical anode comprises TiO_2 nanowires.

23. The dialysis fluid regeneration system of claim 22, wherein individual nanowires have a thickness of about 500 nm.

24. The dialysis fluid regeneration system of claim 22, wherein the TiO_2 nanowires are prepared hydrothermally.

25. The dialysis fluid regeneration system of claim 22, wherein the nanowires are disposed on a substrate, and wherein the individual nanowires are individually electrically coupled to the substrate that carries the nanowires.

26. The dialysis fluid regeneration system of claim 1, further comprising a dialysate solution having a concentration of urea of 10 mM or less.

27. The dialysis fluid regeneration system of claim 1, further comprising a radical scavenger configured to remove oxidative byproducts, radical byproducts, and chlorine.

28. The dialysis fluid regeneration system of claim 1, further comprising a membrane, wherein the membrane is a reverse osmosis (RO) membrane.

29. A dialysis fluid regeneration system, comprising:

a nanostructured photo-electrochemical anode configured for illumination by a source of light; and

a cathode that is permeable to oxygen provided to a dialysis fluid and non-permeable to a liquid of the dialysis fluid, wherein the photo-electrochemical anode is configured to be in contact with the dialysis fluid, and configured to regenerate the dialysis fluid by converting urea in the dialysis fluid into CO_2, N_2 and H_2O through a photo-electrochemical reaction.

30. The dialysis fluid regeneration system of claim 29, wherein the dialysis fluid is a dialysate.

31. The dialysis fluid regeneration system of claim 29, wherein the dialysis fluid regeneration system is a kidney dialysis system.

32. The dialysis fluid regeneration system of claim 31, wherein the dialysis fluid regeneration system is a hemofiltration system, or a hemodialysis system, or a hemodiafiltration system.

33. The dialysis fluid regeneration system of claim 29, further comprising a source of electrical voltage operationally coupled to the photo-electrochemical anode and the cathode, wherein the source of electrical voltage is portable.

34. The dialysis fluid regeneration system of claim 29, wherein the dialysis fluid regeneration system is portable or wearable.

35. The dialysis fluid regeneration system of claim 29, wherein the photo-electrochemical anode and the cathode that is permeable to the oxygen and nonpermeable to the liquid of the dialysis fluid are parts of one dialysis-fluid regeneration cell, and wherein the dialysis fluid regeneration system comprises a plurality of additional dialysis- fluid regeneration cells.

36. The dialysis fluid regeneration system of claim 29, wherein the cathode is an air-breathable cathode.

37. The dialysis fluid regeneration system of claim 36, wherein the cathode is a conductive cloth-based cathode or a conductive paper-based cathode.

38. The dialysis fluid regeneration system of claim 37, wherein the conductive cloth-based cathode comprises a platinum-coated cloth.

39. The dialysis fluid regeneration system of claim 29, further comprising the source of light that is an array of light emitting diodes (LEDs).

40. The dialysis fluid regeneration system of claim 39, wherein the LEDs are arranged in a two-dimensional (2D) array.

41. The dialysis fluid regeneration system of claim 29, further comprising the source of light that is an ultraviolet (UV) light.

42. The dialysis fluid regeneration system of claim 29, further comprising the source of light that is a source of visible light.

43. The dialysis fluid regeneration system of claim 29, wherein the photo-electrochemical anode comprises TiO_2 nanowires.

44. The dialysis fluid regeneration system of claim 43, wherein individual nanowires have a thickness of about 500 nm.

45. The dialysis fluid regeneration system of claim 43, wherein the TiO_2 nanowires are prepared hydrothermally.

46. The dialysis fluid regeneration system of claim 29, further comprising a radical scavenger configured to remove oxidative byproducts, radical byproducts, and chlorine.

47. The dialysis fluid regeneration system of claim 29, further comprising a membrane, wherein the membrane is a reverse osmosis (RO) membrane.

48. A system for treating water, comprising:

a nanostructured photo-electrochemical anode configured for illumination by a source of light; and

a cathode that is permeable to oxygen provided to water and non- permeable to liquid water, wherein the photo-electrochemical anode is configured to be in contact with water, and configured to oxidize impurities in water by a photo- electrochemical reaction.

49. The system for treating water of claim 48, further comprising a source of electrical voltage operationally coupled to the photo-electrochemical anode and the cathode, wherein the source of electrical voltage is portable.

50. The system for treating water of claim 48, wherein the system is portable or wearable.

51. The system for treating water of claim 48, wherein the photo-electrochemical anode, and the cathode that is permeable to the oxygen and nonpermeable to the liquid water are parts of one regeneration cell, and wherein the system for treating water comprises a plurality of additional regeneration cells.

52. The system for treating water of claim 48, wherein the cathode is an air-breathable cathode.

53. The system for treating water of claim 52, wherein the cathode is a conductive cloth-based cathode or a conductive paper-based cathode.

54. The system for treating water of claim 53, wherein the cloth-based cathode comprises a platinum-coated cloth.

55. The system for treating water of claim 48, further comprising the source of light that is an array of light emitting diodes (LEDs).

56. The system for treating water of claim 55, wherein the LEDs are arranged in a two-dimensional (2D) array.

57. The system for treating water of claim 48, further comprising the source of light that is a source of ultraviolet (UV) light.

58. The system for treating water of claim 48, further comprising the source of light that is a source of visible light.

59. The system for treating water of claim 48, wherein the nanostructured photo-electrochemical anode comprises TiO_2 nanowires.

60. The system for treating water of claim 59, wherein individual nanowires have a thickness of about 500 nm.

61. The system for treating water of claim 59, wherein the TiO_2 nanowires are prepared hydrothermally.

62. The system for treating water of claim 48, further comprising a membrane, wherein the membrane is a reverse osmosis (RO) membrane.

63. A kidney dialysis system, comprising:

a nanostructured photo-electrochemical anode configured for illumination by a source of light; and

a cathode that is permeable to oxygen provided to a dialysis fluid and non-permeable to a liquid of the dialysis fluid,

wherein the photo-electrochemical anode is configured to be in contact with the dialysis fluid, and configured to regenerate the dialysis fluid by converting urea in the dialysis fluid into CO_2, N_2 and H_2O through a photo-electrochemical reaction, and

wherein the kidney dialysis system is portable or wearable.

64. The kidney dialysis system of claim 63, wherein the dialysis fluid is a dialysate.

65. The kidney dialysis system of claim 63, wherein the kidney dialysis system is a hemofiltration system, or a hemodialysis system, or a hemodiafiltration system.

66. The kidney dialysis system of claim 63, further comprising a source of electrical voltage operationally coupled to the photo-electrochemical anode and the cathode, wherein the source of electrical voltage is portable.

67. The kidney dialysis system of claim 63, wherein the photo-electrochemical anode, and the cathode that is permeable to the oxygen and nonpermeable to the liquid of the dialysis fluid are parts of one dialysis-fluid

regeneration cell, and wherein the kidney dialysis system comprises a plurality of additional dialysis-fluid regeneration cells.

68. The kidney dialysis system of claim 63, wherein the cathode is an air-breathable cathode.

69. The kidney dialysis system of claim 63, wherein the cathode is a conductive cloth-based cathode or a conductive paper-based cathode.

70. The kidney dialysis system of claim 69, wherein the cloth-based cathode comprises a platinum-coated cloth.

71. The kidney dialysis system of claim 63, further comprising the source of light that is an array of light emitting diodes (LEDs).

72. The kidney dialysis system of claim 71, wherein the LEDs are arranged in a two-dimensional (2D) array.

73. The kidney dialysis system of claim 63, further comprising the source of light that is a source of ultraviolet (UV) light.

74. The kidney dialysis system of claim 63, further comprising the source of light that is a source of visible light.

75. The kidney dialysis system of claim 63, wherein the nanostructured photo- electrochemical anode comprises TiO_2 nanowires.

76. The kidney dialysis system of claim 75, wherein individual nanowires have a thickness of about 500 nm.

77. The kidney dialysis system of claim 75, wherein the TiO_2 nanowires are prepared hydrothermally.

78. The kidney dialysis system of claim 63, further comprising a radical scavenger configured to remove oxidative byproducts, radical byproducts, and chlorine.

79. The kidney dialysis system of claim 63, further comprising a membrane, wherein the membrane is a reverse osmosis (RO) membrane.