Claims

1. A photocatalytic reactor cell assembly, comprising:

an outer cell wall comprising a first tube having a first outer diameter and a first inner diameter;

an inner cell wall comprising a second tube having a second outer diameter and a second inner diameter, wherein the second outer diameter is smaller than the first inner diameter, and wherein the outer cell wall and the inner cell wall are arranged concentrically about a vertical axis to define an annular volume between the outer cell wall and the inner cell wall;

a top compression endcap fitting having an annular shape and comprising a reactant gas inlet;

a bottom compression endcap fitting having an annular shape and comprising a product gas outlet, wherein the top compression endcap fitting and the bottom compression endcap fittings respectively form a top seal and a bottom seal with the outer cell wall and the inner cell wall;

a photocatalyst packed bed positioned in the annular volume between the outer cell wall and the inner cell wall, wherein the photocatalyst packed bed comprises a photocatalyst;

a porous base filter to position the photocatalyst packed bed in the annular volume, wherein the porous base filter is on an underside of the photocatalyst packed bed closer to the bottom compression endcap fitting than to the top compression endcap fitting, and wherein the porous base filter has a pore size chosen to be gas permeable but impermeable to the photocatalyst in the photocatalyst packed bed; and

a light housing comprising an outer portion and an inner portion, wherein the outer portion is arranged concentrically around the vertical axis outside the outer cell wall,

wherein the inner portion is arranged concentrically around the vertical axis inside the inner cell wall, and wherein at least one of the outer portion ~~and~~ or the inner portion comprises a circumferential array of photon emitters arranged to uniformly emit photons incident on the photocatalyst packed bed,

whereby the emission of photons incident on the photocatalyst packed bed activates continuous photo-induced gas-phase reactions as at least one gaseous reactant introduced via the gas inlet flows through the photocatalyst packed bed and at least one resultant gaseous product exits via the gas outlet.

~~2. The photocatalytic reactor cell assembly of claim 1, wherein the first tube is cylindrical.~~

~~3. The photocatalytic reactor cell assembly of claim 1 or claim 2, wherein the first tube has a circular cross section.~~

~~4. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the second tube is cylindrical.~~

~~5. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the second tube has a circular cross section.~~

~~6. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the first tube and the second tube are cylindrical.~~

~~7.~~ 2. The photocatalytic reactor cell assembly of ~~any of the preceding claims~~claim 1, wherein the first tube and the second tube have a circular cross section.

~~8.~~ 3. The photocatalytic reactor cell assembly of ~~any of the preceding claims~~claim 1 or 2, wherein at least a portion of at least one of the outer cell wall ~~and~~ or the inner cell wall is constructed of a material that is transparent to the photons emitted by the photon emitters.

~~9. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least a portion of at least one of the outer cell wall and the inner cell wall is transparent to photons in the visible light spectrum.~~

~~10. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least a portion of at least one of the outer cell wall and the inner cell wall is transparent to photons in the near-IR spectrum.~~

~~11. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least one of the outer cell wall and the inner cell wall comprises glass tubing.~~

~~12.~~ 4. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 3, wherein at least one of the outer cell wall ~~and~~ or the inner cell wall comprises fused quartz glass, borosilicate glass, a metallic material, or glass tubing.

~~13. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least one of the outer cell wall and the inner cell wall comprises borosilicate glass.~~

~~14. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least one of the outer cell wall and the inner cell wall comprises a metallic material.~~

~~15.~~ 5. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 4, wherein at least a first portion of at least one of the outer cell wall ~~and~~ or the inner cell wall is constructed of a material that is transparent to the photons emitted by the photon emitters, and wherein at least a second portion of at least one of the outer cell wall ~~and~~ or the inner cell wall comprises a reflective surface to reflect emitted photons into the photocatalyst packed bed.

~~16. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least a first portion of at least one of the outer cell wall and the inner cell wall is constructed of a material~~

~~that is transparent to the photons emitted by the photon emitters, and wherein at least a second portion of at least one of the outer cell wall and the inner cell wall comprises a scattering surface to scatter emitted photons into the photocatalyst packed bed.~~

~~17.~~ 6. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 5, wherein the photocatalyst packed bed comprises the photocatalyst co-precipitated with a support material.

~~18. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the photocatalyst comprises antenna-reactor plasmonic nanoparticles.~~

~~19.~~ 7. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 6, wherein the photocatalyst packed bed is positioned vertically in a middle portion of the annular volume, and wherein an upper portion of the annular volume closest to the top compression endcap fitting is devoid of the photocatalyst packed bed to provide sufficient headspace for reactant gas mixing.

~~20.~~ 8. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 7, wherein the top compression endcap fitting and the bottom compression endcap fitting are constructed of stainless steel (SS316), an austenitic nickel-chromium-based alloy, a nickel-chromium-iron-molybdenum alloy, or aluminum.

~~21. The photocatalytic reactor cell assembly of any of claims 1-19, wherein the top compression endcap fitting and the bottom compression endcap fitting are constructed of an austenitic nickel-chromium-based alloy.~~

~~22. The photocatalytic reactor cell assembly of any of claims 1-19, wherein the top compression endcap fitting and the bottom compression endcap fitting are constructed of a nickel-chromium-iron-molybdenum alloy.~~

~~23. The photocatalytic reactor cell assembly of any of claims 1-19, wherein the top compression endcap fitting and the bottom compression endcap fitting are constructed of aluminum.~~

~~24. The photocatalytic reactor cell assembly of any of the preceding claims, wherein a portion of at least one of the top compression endcap fitting and the bottom compression endcap fitting facing the photocatalyst packed bed is polished to reflect emitted photons into the photocatalyst packed bed.~~

~~25. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the top compression endcap fitting has at least one of a first outer circumferential flange to fit around a top portion of the outer cell wall or a first inner circumferential flange to fit inside a top portion of the inner cell wall.~~

~~26. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the bottom compression endcap fitting has at least one of a second outer circumferential flange to fit around a bottom portion of the outer cell wall or a second inner circumferential flange to fit inside a bottom portion of the inner cell wall.~~

~~27.~~ 9. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 8, further comprising a tension rod coupled to each of the top compression endcap fitting and the bottom compression endcap fitting to exert a compression force sufficient to cause the top seal and the bottom seal to be formed.

~~28. The photocatalytic reactor cell assembly of claim 27, wherein the tension rod is arranged to be co-linear with the vertical axis about which the outer cell wall and the inner cell wall are concentrically arranged, and wherein the tension rod comprises threads cooperating with at least one threaded fastener to facilitate tightening of the top compression endcap fitting and the bottom compression endcap fitting onto the outer cell wall and the inner cell wall.~~

~~29. The photocatalytic reactor cell assembly of claim 27 or claim 28, wherein the top compression endcap fitting and the bottom compression endcap fitting each comprise a support through which the tension rod exerts the compression force.~~

~~30. The photocatalytic reactor cell assembly of claim 29, wherein the tension rod and the supports are constructed of aluminum.~~

~~31. The photocatalytic reactor cell assembly of any of the preceding claims, further comprising a plurality of tension rods coupled to each of the top compression endcap fitting and the bottom compression endcap fitting to exert a compression force sufficient to cause the top seal and the bottom seal to be formed.~~

~~32.~~ 10. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 9, further comprising at least one gasket to assist in causing at least one of the top seal or the bottom seal to be formed.

~~33.~~ 11. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 10, further comprising at least one O-ring to assist in causing at least one of the top seal or the bottom seal to be formed.

~~34. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the outer portion of the light housing is cylindrical.~~

~~35. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the outer portion of the light housing has a circular cross section.~~

~~36. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the inner portion of the light housing is cylindrical.~~

~~37. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the inner portion of the light housing has a circular cross section.~~

~~38. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the inner portion of the light housing and the outer portion of the light housing are cylindrical.~~

~~39.~~ 12. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 11, wherein the outer portion of the light housing and the inner portion of the light housing have a circular cross section.

~~40. The photocatalytic reactor cell assembly of any of the preceding claims, wherein at least one of the outer portion of the light housing or the inner portion of the light housing comprises an aluminum frame upon which the circumferential array of photon emitters is mounted.~~

~~41.~~ 13. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 12, wherein at least one of the outer portion of the light housing or the inner portion of the light housing comprises a cooling block upon which the circumferential array of photon emitters is mounted, and wherein the cooling block has at least one cooling passage through which a cooling fluid passes.

~~42.~~ 14. The photocatalytic reactor cell assembly of ~~any of the preceding claims~~claim 13, wherein the cooling block comprises aluminum walls defining a receptacle through which the cooling fluid is passed at a predetermined flow rate.

~~43. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the cooling fluid has a predetermined heat capacity.~~

~~44. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the circumferential array of photon emitters comprises a plurality of LEDs mounted on at least one of~~

~~the aluminum walls of the cooling block, whereby the cooling fluid passing through the receptacle assists in cooling the plurality of LEDs.~~

~~45. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the circumferential array of photon emitters comprises a plurality of LEDs, and wherein at least one of the cylindrical shell of the light housing or the inner portion of the light housing comprises a cooling block having at least one of a plurality of coolant passages or a plurality of baffles for passing a cooling fluid through the cooling block to assist in cooling the plurality of LEDs.~~

~~46.~~ 15. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 14, wherein the outer portion comprises an outer cooling block and the inner portion comprises an inner cooling block, the outer cooling block and the inner cooling block being configured to assist in cooling the photon emitters.

~~47.~~ 16. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 15, wherein the outer portion of the light housing comprises the circumferential array of photon emitters arranged on an inner surface of the outer portion to uniformly emit photons incident on the photocatalyst packed bed.

~~48.~~ 17. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 15, wherein the inner portion of the light housing comprises the circumferential array of photon emitters arranged on an outer surface of the inner portion to uniformly emit photons incident on the photocatalyst packed bed.

~~49.~~ 18. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 15, wherein the outer portion of the light housing comprises a first portion of the circumferential array of photon emitters arranged on an inner surface of the outer portion to uniformly emit photons incident on the photocatalyst packed bed, and wherein the inner portion of the light housing comprises a second portion of the circumferential array of photon emitters arranged on an outer surface of the inner portion to uniformly emit photons incident on the photocatalyst packed bed.

~~50. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the outer portion of the light housing is of a clamshell design and comprises two sections coupled by a hinge to allow for installation or removal of the outer portion in the photocatalytic reactor cell assembly.~~

~~51. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the inner portion of the light housing fastens to the tension rod.~~

~~52.~~ 19. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 18, wherein the outer portion and the inner portion are each connected to at least one of the supports on at least one of the top compression endcap fitting ~~and~~ or the bottom compression endcap fitting.

~~53. The photocatalytic reactor cell assembly of claim 52, wherein the supports are constructed of aluminum.~~

~~54. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the light housing is fluid-cooled.~~

~~55. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the light housing is water-cooled.~~

~~56. The photocatalytic reactor cell assembly of any of the preceding claims in which the photon emitters are LEDs, wherein the light housing comprises a cooling system to maintain a surface on which the photon emitters are mounted at a temperature not exceeding 150 degrees Celsius.~~

~~57. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the light housing comprises at least one heat sink.~~

~~58. The photocatalytic reactor cell assembly of claim 57, wherein the heat sink is constructed of aluminum.~~

~~59.~~ 20. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 19, wherein the light housing further comprises integrated control electronics to control the photon emitters.

~~60. The photocatalytic reactor cell assembly of any of the preceding claims, wherein both the outer portion and the inner portion have annular cross sections.~~

~~61. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the circumferential array of photon emitters comprises a plurality of LED boards adjacent to one another, each LED board comprising a plurality of LEDs.~~

~~62.~~ 21. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 20, wherein the photon emitters are selected to emit photons having a sufficient energy and wavelength to activate the photo-induced gas-phase reactions.

~~63. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the photon emitters comprise Light-Emitting Diodes (LED) to emit photons in the visible light spectrum.~~

~~64. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the photon emitters comprise Infrared (IR) lamps to emit photons in the near-IR spectrum.~~

~~65.~~ 22. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 21, wherein the photon emitters ~~are selected from the group consisting of~~ comprise UV lamps, IR lamps, arc lamps, and/or LEDs.

~~66. The photocatalytic reactor cell assembly of any of the preceding claims, further comprising drivers for the photon emitters, wherein the drivers are selected to operate at 50% or greater power load in order to improve driver efficiency.~~

~~67.~~ 23. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 21, wherein the circumferential array of photon emitters comprises a plurality of infrared (IR) lamps arranged adjacent to one another annularly around the vertical axis.

~~68.~~ 24. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 21, wherein the outer portion comprises the circumferential array of photon emitters in form of infrared (IR) lamps arranged adjacent to one another annularly around the vertical axis and outside of the outer cell wall, wherein each IR lamp comprises a reflective coating to reflect IR radiation toward the ~~photocatalytic~~ photocatalyst packed bed, and wherein the reflective coating of each IR lamp is on a surface of the IR lamp distal from the vertical axis.

~~69.~~ 25. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 21, wherein the inner portion comprises the circumferential array of photon emitters in form of infrared (IR) lamps arranged adjacent to one another annularly around the vertical axis and inside of the inner cell wall, wherein each IR lamp comprises a reflective coating to reflect IR radiation toward the ~~photocatalytic~~ photocatalyst packed bed, and wherein the reflective coating of each IR lamp is on a surface of the IR lamp proximal to the vertical axis.

~~70.~~ 26. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 25, wherein the porous base filter comprises a gas-permeable structural material.

~~71. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the porous base filter comprises at least one of porous metal, quartz wool, or ceramic.~~

~~72. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the porous base filter comprises stainless steel (SS316), an austenitic nickel-chromium-based alloy, or a nickel-chromium-iron-molybdenumm alloy.~~

~~73. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the porous base filter has an annular shape.~~

~~74. The photocatalytic reactor cell assembly of any of the preceding claims, further comprising a heater to heat the annular volume, thereby increasing the reaction rate of the photo-induced gas-phase reactions.~~

~~75. The photocatalytic reactor cell assembly of any of the preceding claims, wherein the outer portion of the light housing is a heater that heats the annular volume to thereby increase the reaction rate of the photo-induced gas-phase reaction.~~

~~76. The photocatalytic reactor cell assembly of claim 74 or claim 75, wherein the heater is selected from a tube furnace heater or a band heater.~~

~~77.~~ 27. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 26, further comprising an immersion infrared (IR) coil lamp disposed in a helical quartz tube in the annular volume.

~~78.~~ 28. The photocatalytic reactor cell assembly of any ~~of the preceding claims~~one of claims 1 to 26, further comprising a heater embedded in the annular volume, wherein the heater comprises a plurality of infrared (IR) lamps arranged adjacent to one another annularly around the vertical axis between the inner cell wall and the outer cell wall.

~~79. The photocatalytic reactor cell assembly of any of the preceding claims, further comprising an annular heater immersed in the annular volume.~~

~~80.~~ 29. The photocatalytic reactor cell assembly of any of ~~the preceding claims~~claims 1 to 28, wherein at least one of the first tube or the second tube comprises a plurality of cylindrical portions having different diameters, and wherein the cylindrical portions are joined end-to-end via angular connecting portions.