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, wherein the annular volume comprises an upper portion and a middle portion;

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 to position the photocatalyst packed bed vertically in the middle portion and to provide sufficient headspace for reactant gas mixing in the upper portion, 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, wherein at least one of the outer portion or the inner portion comprises a circumferential array of photon emitters arranged to uniformly emit photons incident on the photocatalyst packed bed, and wherein at least a portion of at least one of the outer cell wall or the inner cell wall is constructed of a material that is transparent to the photons emitted by the photon emitters,

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 and the second tube have a circular cross section.

3. The photocatalytic reactor cell assembly of any one of claims 1 to 2, wherein at least one of the outer cell wall or the inner cell wall comprises fused quartz glass, a metallic material, borosilicate glass, or glass tubing.

4. The photocatalytic reactor cell assembly of any one of claims 1 to 3, wherein at least a first portion of at least one of the outer cell wall 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 or the inner cell wall comprises a reflective surface to reflect emitted photons into the photocatalyst packed bed.

5. The photocatalytic reactor cell assembly of any one of claims 1 to 4, wherein the photocatalyst packed bed comprises the photocatalyst co-precipitated with a support material.

6. The photocatalytic reactor cell assembly of any one of claims 1 to 5, wherein the upper portion of the annular volume closest to the top compression endcap fitting is devoid of the photocatalyst packed bed.

7. The photocatalytic reactor cell assembly of any one of claims 1 to 6, 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.

8. The photocatalytic reactor cell assembly of any one of claims 1 to 7, 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.

9. The photocatalytic reactor cell assembly of any one of claims 1 to 8, further comprising at least one gasket to assist in causing at least one of the top seal or the bottom seal to be formed.

10. The photocatalytic reactor cell assembly of any one of claims 1 to 9, 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.

11. The photocatalytic reactor cell assembly of any one of claims 1 to 10, wherein the outer portion of the light housing and the inner portion of the light housing have a circular cross section.

12. The photocatalytic reactor cell assembly of any one of claims 1 to 11, 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.

13. The photocatalytic reactor cell assembly of claim 12, wherein the cooling block comprises aluminum walls defining a receptacle through which the cooling fluid is passed at a predetermined flow rate.

14. The photocatalytic reactor cell assembly of any one of claims 1 to 13, 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.

15. The photocatalytic reactor cell assembly of any one of claims 1 to 14, 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.

16. The photocatalytic reactor cell assembly of any one of claims 1 to 14, 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.

17. The photocatalytic reactor cell assembly of any one of claims 1 to 14, 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.

18. The photocatalytic reactor cell assembly of any one of claims 1 to 17, 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 or the bottom compression endcap fitting.

19. The photocatalytic reactor cell assembly of any one of claims 1 to 18, wherein the light housing further comprises integrated control electronics to control the photon emitters.

20. The photocatalytic reactor cell assembly of any one of claims 1 to 19, wherein the photon emitters are selected to emit photons having a sufficient energy and wavelength to activate the photo-induced gas-phase reactions.

21. The photocatalytic reactor cell assembly of any one of claims 1 to 20, wherein the photon emitters comprise UV lamps, IR lamps, arc lamps, and/or LEDs.

22. The photocatalytic reactor cell assembly of any one of claims 1 to 20, wherein the circumferential array of photon emitters comprises a plurality of infrared (IR) lamps arranged adjacent to one another annularly around the vertical axis.

23. The photocatalytic reactor cell assembly of any one of claims 1 to 20, 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 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.

24. The photocatalytic reactor cell assembly of any one of claims 1 to 20, 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 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.

25. The photocatalytic reactor cell assembly of any one of claims 1 to 24, wherein the porous base filter comprises a gas-permeable structural material.

26. The photocatalytic reactor cell assembly of any one of claims 1 to 25, further comprising an immersion infrared (IR) coil lamp disposed in a helical quartz tube in the annular volume.

27. The photocatalytic reactor cell assembly of any one of claims 1 to 25, 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.

28. The photocatalytic reactor cell assembly of any one of claims 1 to 27, 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.