Claims

1. A method for producing an extrudate photocatalyst comprising:

co-precipitating at least two solutions to deposit an active metal on a support, thereby forming a slurry;

centrifugating the slurry to form a paste in which unreacted chemicals, byproducts, and excess solvent from the co-precipitating have been removed;

drying the paste to form a dried powder;

milling the dried powder to form a milled dried powder having a homogeneous size of catalyst particles;

mixing the milled dried powder with a binder, a porogen, and a peptizing agent to produce a mixture;

adding a solvent to the mixture to form a dough;

feeding the dough through an extruder to create one or more extrudates each having a predetermined shape and cross-section;

drying the extrudates; and

thermally treating the extrudates after drying.

2. The method of claim 1, further comprising selecting amounts of the peptizing agent and the solvent to form the dough such that the extrudates, after the drying and thermally treating, will have a correspondingly proportional crushing strength and porosity.

3. The method of claim 1, further comprising cutting the extrudates to create extrudates having a shorter length.

4. The method of any of claims 1 to 3, wherein the binder is an organic binder.

5. The method of any of claims 1 to 3, wherein the binder is guar gum.

6. The method of any of claims 1 to 3, wherein the binder is selected from the group consisting of alumina, silica, silica-alumina, titania, zirconia, and national clay.

7. The method of any of claims 1 to 3, wherein the porogen is selected from the group consisting of a starch, a flax, and a carbon black material.

8. The method of any of claims 1 to 3, wherein the porogen thermally decomposes during the drying of the extrudates to thereby remove the porogen from the extrudates.

9. The method of any of claims 1 to 3, wherein at least one of the at least two solutions comprises a photocatalytic material selected from plasmonic and non-plasmonic metals, metal oxides, semiconductors, oxides, or materials with free carriers.

10. The method of any of claims 1 to 3, wherein thermally treating the extrudates comprises calcination of the extrudates in the presence of air at a temperature range of 150-800°C for more than 2 hours.

11. The method of any of claims 1 to 3, wherein thermally treating the extrudates comprises reduction of the extrudates in the presence of hydrogen at a temperature range of at least 150-800°C for at least 2 hours.

12. The method of any of claims 1 to 3, further comprising (a) analyzing solvent content in the paste formed via centrifugation to determine if the paste has a solvent content within a predetermined range, and (b) if not, adjusting duration of the centrifugation.

13. The method of claim 1, wherein the extruder comprises a die having one or more holes through which the paste or dough is fed, and wherein the shape and dimension of each of the holes are selected to respectively define a cross-sectional shape and dimension of each of the extrudates.

14. The method of claim 13, wherein the holes are circular with a diameter of at least 1 mm and wherein the extrudates have a circular cross section with a diameter of at least 1 mm.

15. The method of claim 3, wherein cutting the extrudates to create extrudates having the shorter length comprises cutting the extrudates to have a length-to-diameter ratio of at least 10, and wherein the diameter is at least 1 mm.

16. The method of claim 3, wherein cutting the extrudates to create extrudates having the shorter length comprises cutting the extrudates to have a length-to-diameter ratio of 100, and wherein the diameter is at least 1 mm.

17. The method of claim 3, wherein cutting the extrudates to create extrudates having the shorter length comprises cutting the extrudates to have a length-to-diameter ratio of 1000, and wherein the diameter is at least 1 mm.

18. The method of claim 13, wherein the shape of each of the holes is selected from the group consisting of a circle, a cloverleaf, a dumbbell, a symmetrical polylobate, or an asymmetrical polylobate, to thereby cause each of the extrudates to have corresponding respective cross-sectional shapes selected from the group consisting of the circle, the cloverleaf, the dumbbell, the symmetrical polylobate, or the asymmetrical polylobate.

19. The method of any of claims 1 to 3, wherein the extrudates have a crushing strength of at least 10 N/mm^2.

20. The method of any of claims 1 to 3, wherein the extrudates have optical and chemical properties substantially matching those of the dried powder.

21. The method of any of claims 1 to 3, further comprising loading the extrudates as a photocatalyst packed bed into a photoreactor, wherein the extrudates reduce a pressure drop in the photoreactor compared to a non-extrudate photocatalyst.

22. The method of claim 21, wherein loading the extrudates comprises positioning the extrudates on a delimiter as the photocatalyst packed bed in an annular volume of the photoreactor between an outer cell wall of the photoreactor and an inner cell wall of the photoreactor.

23. The method of claim 21, wherein the photoreactor is constructed of glass or quartz, further comprising passing a feed gas through the photocatalyst packed bed comprising the extrudates.

24. An extrudate photocatalyst produced in accordance with the method of any of claims 1 to 3.

25. 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, 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, and wherein at least one of the outer cell wall or the inner cell wall is constructed of glass or quartz;

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 an extruded mesoporous photocatalyst having a crushing strength of at least 10 N/mm2, and wherein the extruded mesoporous photocatalyst reduces a pressure drop in the photocatalytic reactor cell compared to a non-extrudate 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 extruded mesoporous photocatalyst in the photocatalyst packed bed; and

a light housing comprising a circumferential array of photon emitters arranged to emit photons incident on the photocatalyst packed bed,

whereby emitted photons incident on the photocatalyst packed bed activate 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.

26. The photocatalytic reactor cell assembly of claim 25, wherein the porosity of the extruded mesoporous photocatalyst is in a range of 0.3 - 0.45.

27. A method comprising:

mixing a photocatalyst powder, a binder, and a porogen to create a homogeneous mixture;

adding a solvent to the homogeneous mixture while stirring the homogeneous mixture, wherein the solvent comprises water or diluted acid;

mixing the solvent and the homogeneous mixture to form a thickened wet dough material;

feeding the thickened wet dough material through an extruder having an extruder auger tube terminating at a die having holes of predetermined shape and cross-section to thereby create a plurality of extrudates having the predetermined shape and cross-section;

cutting the plurality of extrudates with a cutter to create a plurality of cut extrudates having a desired cross-section-to-length aspect ratio;

drying the plurality of cut extrudates; and

applying a thermal treatment to the plurality of cut extrudates.

28. A photocatalyst extrudate produced via the method of claim 27, wherein the photocatalyst extrudate has a crushing strength of at least 10 N/mm^2 and a porosity in a range of 0.3 - 0.45.

29. The method of claim 3, further comprising shaping the extrudates having the shorter length into a sphere using a spheronizer, wherein the extrudates having the shorter length comprises a length-to-diameter ratio of at least 1, and wherein the diameter is at least 1mm.