PHOTOCATALYTIC REACTOR CELL

BACKGROUND OF THE DISCLOSURE

1. Related Applications

[0001] The present application claims priority to and hereby incorporates by reference the entireties of the following U.S. patent applications: U.S. Provisional Patent Application No. 62/525,301, filed on June 27, 2017, U.S. Provisional Patent Application No. 62/525,305, filed on June 27, 2017, U.S. Provisional Patent Application No. 62/525,380, filed on June 27, 2017, and U.S. Provisional Patent Application No. 62/586,675, filed on November 15, 2017.

[0002] In addition, the entireties of the following applications are incorporated by reference herein: International Patent Application No. PCT/US18/32375, filed on May 11, 2018, U.S. Patent Application No. 15,977,843, filed on May 11, 2018, and International Patent Application No. (to be assigned), titled "Photocatalytic Reactor Having Multiple Photocatalytic Reactor Cells," filed concurrently herewith.

2. Field of the Disclosure

[0003] The present disclosure relates generally to photocatalytic reactor cells comprising an enclosure and one or more plasmonic photocatalysts on a catalyst support disposed within the enclosure.

3. Technical Background

[0004] Industrial processes depend extensively on heterogeneous catalysts for chemical production and mitigation of environmental pollutants. These processes often rely on metal nanoparticles dispersed into high surface area support materials to both maximize catalytically active surface area and for the most cost-effective use of the catalysts (such as palladium, platinum, ruthenium, or rhodium). The catalytic processes utilizing transition metal nanoparticles are often energy intensive, relying on high temperatures and pressures to maximize catalytic activity. Thus, there remains a need for efficient and cost-effective catalytic reactors and systems.

SUMMARY OF THE DISCLOSURE

[0005] The inventors have found efficient reactor cells that utilize an artificial or natural light source. The reactor cells of the disclosure can be designed to maximize absorption of one or more target wavelengths and/or catalyze a desired chemical reaction. As a result, the reactor cells disclosed herein may be cost effective and environmentally sustainable solutions for many current industrial processes.

[0005a] Aspects of the invention are defined in the independent claims. Some optional features of the invention are defined in the dependent claims.

[0006] Thus, in one exemplary arrangement, the present disclosure provides a reactor cell comprising: an optically transparent enclosure comprising at least one input and at least one output; and one or more plasmonic photocatalysts on a catalyst support disposed within the enclosure, wherein the plasmonic photocatalyst comprises a catalyst coupled to a plasmonic material, such as through a physical, electronic, thermal, or optical coupling. Upon application of a light source, the reactor cell is configured to transform at least one reactant into at least one reformate.

[0007] Other exemplary arrangements are provided in methods for using one or more of the disclosed reactor cells to transform reactants. Specifically, the disclosure provides methods for transforming at least one reactant into at least one reformate. The method includes: (a) adding at least one reactant into a reactor cell of the disclosure; and (b) illuminating, via the at least one light source, at least an interior of the reactor cell.

[0008] In another exemplary arrangement, the present disclosure provides a reactor cell comprising: an enclosure comprising at least one input, at least one output, and a central cavity; a light source disposed in the central cavity; and one or more plasmonic photocatalysts on a catalyst support disposed within the enclosure and substantially surrounding the central cavity, wherein the plasmonic photocatalyst comprises a catalyst coupled to a plasmonic material, such as through a physical, electronic, thermal, or optical coupling.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The accompanying drawings are included to provide a further understanding of the methods and devices of the disclosure, and are incorporated in and constitute a part of this specification. The drawings are not necessarily to scale, and sizes of various elements may be distorted for clarity and/or illustrated as simplistic representations in order to promote comprehension. The drawings illustrate one or more embodiment(s) of the disclosure, and together with the description, serve to explain the principles and operation of the disclosure.

[0010] **Figure 1A** is a cross-sectional side view of a reactor cell according to one embodiment of the disclosure.

[0011] **Figure1B** is exploded perspective side view of a reactor cell according to one embodiment of the disclosure.

[0012] **Figure 2** is a cross-sectional detail view of an example configuration of the reactor cell having a catalyst support in bead form.

What is claimed is:

1. A fixed-bed reactor cell for transforming one or more reactant gases, the fixed-bed reactor cell comprising:

an optically transparent cylindrical enclosure;

a first fitting configured to attach the reactor cell at a first end of the enclosure to at least one delivery channel for receiving at least one reactant input gas;

a second fitting configured to attach the reactor cell at a second end of the enclosure to at least one delivery channel for outputting at least one output gas; the fixed-bed reactor cell being configured for:

a catalyst support to be packed as a fixed bed substantially filling the enclosure; and

a first plasmonic photocatalyst to be supported by the catalyst support, wherein the first plasmonic photocatalyst comprises a catalyst coupled to a plasmonic material having a plasmon resonant frequency to catalyze a desired chemical reaction,

wherein, upon application of a light source to substantially an entirety of at least an interior of the enclosure while the at least one reactant input gas is passed through the enclosure, the reactor cell is configured to transform the at least one reactant input gas into at least one output gas via the at least one reactant input gas reacting with at least the first plasmonic photocatalyst.

2. The reactor cell of claim 1, wherein the optically transparent enclosure has at least 50% transmittance for at least one predetermined light wavelength.

3. The reactor cell of claim 1, wherein the optically transparent enclosure comprises glass, borosilicate glass, quartz, fused quartz, aluminosilicate glass, lithium-aluminosilicate glass, sapphire, or combinations thereof.

4. The reactor cell of claim 1, wherein the catalyst support is selected to have an absorbance sufficiently low to catalyze the transformation of the at least one reactant input gas into the at least one output gas for at least one predetermined light wavelength.

5. The reactor cell of claim 1, wherein the catalyst support comprises silica, quartz, fused quartz, glass, borosilicate glass, sapphire, diamond, or combination thereof.

6. The reactor cell of claim 1, wherein the catalyst support is an aerogel comprising silicon dioxide, aluminum oxide, titanium dioxide, zirconium dioxide, holmium oxide, samarium oxide, erbium oxide, neodymium(III) oxide, or a combination thereof.

7. The reactor cell of claim 1, wherein the catalyst support is an aluminum oxide.

8. The reactor cell of claim 1, configured for a second plasmonic photocatalyst to be supported by the catalyst support, wherein the second plasmonic photocatalyst differs from the first plasmonic photocatalyst.

9. The reactor cell of claim 1, wherein the enclosure has an inner diameter ranging from 0.2 cm to 30 cm, or 0.5 cm to 10 cm, and a length ranging from 10 cm to 2 m, or 50 cm to 1 m.

10. The reactor cell of claim 1, wherein the light source comprises at least one LED, metal halide bulb, high pressure sodium bulb, xenon lamp, incandescent bulb, fluorescent bulb, halogen bulb, HID, laser or combination thereof.

11. The reactor cell of claim 1, wherein the optically transparent enclosure further comprises an outer cavity and a central cavity arranged coaxially with the outer cavity, wherein the outer cavity contains at least the first plasmonic photocatalyst on the catalyst support and substantially surrounds the central cavity, and wherein the central cavity is configured to receive at least one of the light source and a thermal management feature.

12. The reactor cell of claim 11, wherein the outer cavity of the optically transparent enclosure comprises a reflective surface facing the central cavity.

13. The reactor cell of claim 11, wherein the thermal management feature includes a fluid input coupled to a first end of the central cavity and a fluid output coupled to a second end of the central cavity such that fluid may flow through the reactor cell to add or remove heat from the reactor cell.

14. The reactor cell of claim 11, wherein the thermal management feature comprises at least one metal rod or a plurality of metal wires.

15. A method for transforming at least one reactant gas using a fixed-bed reactor cell, the fixed-bed reactor cell comprising:

an optically transparent cylindrical enclosure;

a first fitting configured to attach the reactor cell at a first end of the enclosure to at least one delivery channel for receiving at least one reactant input gas;

a second fitting configured to attach the reactor cell at a second end of the enclosure to a least one delivery channel for outputting at least one output gas;

a catalyst support packed as a fixed bed substantially filling the enclosure;

a first plasmonic photocatalyst supported by the catalyst support, wherein the first plasmonic photocatalyst comprises a catalyst coupled to a plasmonic material having a plasmon resonant frequency to catalyze a desired chemical reaction, the method comprising:

supplying at least one reactant input gas via the at least one delivery channel to the first fitting of the reactor cell;

illuminating, via at least one light source, at least an interior of the reactor cell; and

outputting at least one output gas from the second fitting of the reactor cell,

wherein, upon application of the at least one light source to substantially an entirety of at least an interior of the enclosure while the at least one reactant input gas is passed through the enclosure, the reactor cell transforms the at least one reactant input gas into the at least one output gas via the at least one reactant input gas reacting with at least the first plasmonic photocatalyst.

16. The method of claim 15, further comprising heating the reactor cell via a thermal management feature disposed at least partially within the enclosure.

17. The method of claim 15, further comprising heating the at least one cell via only the at least one reactant reacting with the plasmonic photocatalyst, without applying any additional dedicated heating source.

18. A reactor cell comprising:

an enclosure comprising at least one input, at least one output, and a central cavity;

a light source disposed in the central cavity; and

at least one plasmonic photocatalyst on a catalyst support disposed within the enclosure and substantially surrounding the central cavity, wherein the plasmonic photocatalyst comprises a catalyst coupled to a plasmonic material.

19. The reactor cell of claim 18, wherein the outer cavity of the transparent enclosure comprises a reflective surface facing the central cavity.

20. The reactor cell of claim 1, wherein the enclosure has a length ranging from 50 cm to 1 m.

21. The reactor cell of claim 8, wherein the second plasmonic photocatalyst has a different plasmon resonant frequency from that of the first plasmonic photocatalyst.

22. The reactor cell of claim 8, wherein the second plasmonic photocatalyst has a different diameter from that of the first plasmonic photocatalyst.

23. The reactor cell of claim 8, wherein the first plasmonic photocatalyst and second plasmonic photocatalyst are arranged in different layers from one another.

24. The reactor cell of claim 8, wherein the first plasmonic photocatalyst absorbs a first wavelength range relative to other wavelengths, while the second plasmonic photocatalyst absorbs a second wavelength range relative to other wavelengths, and wherein the first wavelength range differs from the second wavelength range.