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EXMO0116PCT

CLAIMS

1. A system for removing carbon nanotubes from a continuous reactor effluent, comprising:

a first separation vessel configured to:

isolate catalyst particles from the continuous reactor effluent; and

return the catalyst particles to a reactor; and

a second separation vessel configured to:

isolate the carbon nanotubes from the continuous reactor effluent; and

generate a stream comprising gaseous components from the continuous reactor effluent.

2. The system of claim 1, wherein the reactor comprises a fluidized bed reactor that is configured to accept the catalyst particles from the first separation vessel.

3. The system of claim 1, wherein the stream comprises residual carbon nanotubes.

4. The system of claim 1, wherein the first separation vessel, the second separation vessel, or both comprises a gravity separation vessel.

5. The system of claim 4, wherein the gravity separation vessel comprises a cyclonic separator.

6. The system of claim 5, wherein the cyclonic separator comprises a single cyclone.

7. The system of claim 5, wherein the cyclonic separator comprises multiple cyclones.

8. The system of claim 4, wherein the gravity separation vessel comprises a drift separator.

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9. The system of claim 1, wherein the first separation vessel, the second separation vessel, or both comprises an electrostatic separation unit configured to impose an electric field.

10. The system of claim 1, wherein the first separation vessel, the second separation vessel, or both comprises a magnetic separation vessel.

11. The system of claim 1, wherein the first separation vessel, the second separation vessel, or both comprises a filter.

12. The system of claim 11, wherein the filter comprises a sintered ceramic filter, a sintered metal filter, a fabric bag filter, or a fluidized bed filter, or any combinations thereof.

13. The system of claim 11, wherein the filter is configured to perform a self-cleaning procedure to remove any remaining carbon nanotubes.

14. A method for removing carbon nanotubes from a continuous reactor effluent, comprising:

flowing the continuous reactor effluent through a catalyst separation vessel that removes catalyst particles and returns the catalyst particles to the reactor;

flowing the continuous reactor effluent from the catalyst separation vessel through a carbon nanotube separation vessel;

separating carbon nanotubes from the continuous reactor effluent in the carbon nanotube separation vessel; and

generating a stream comprising gaseous components from the continuous reactor effluent.

15. The method of claim 14, comprising isolating the carbon nanotubes from the stream comprising gaseous components through an electromagnetic separation process.

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16. The method of claim 14, comprising isolating the carbon nanotubes from the stream comprising gaseous components through a gravity separation process.

17. The method of claim 16, wherein the gravity separation process comprises using a cyclonic separator.

18. The method of claim 17, wherein the cyclonic separator comprises a multicyclonic separator.

19. The method of claim 14, wherein the carbon nanotube separation vessel is configured to generate the carbon nanotubes and the stream comprising gaseous components through a density based separation process.

20. The method of claim 14, comprising:
isolating an excess catalyst stream from the continuous reactor effluent; and
flowing the excess catalyst stream to a reactor.

21. A system for creating a purified stream of carbon nanotubes from a gas flow, comprising:
a separation system configured to generate a first purified stream of the carbon nanotubes and a first residual stream comprising gaseous components from the gas flow; and
a filtration system configured to generate a second purified stream of the carbon nanotubes and a second residual stream comprising impurities from the first purified stream of the carbon nanotubes.

22. The system of claim 21, wherein the separation system is configured to:
isolate an excess reagent stream from the gas flow; and
flow the excess reagent stream to a reactor.

23. The system of claim 21, wherein the separation system comprises a multicyclonic separation system or a single cyclonic separation system.

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24. The system of claim 21, wherein the separation system comprises an electrostatic precipitator.

25. The system of claim 21, wherein the separation system comprises a magnetic separation system.

26. The system of claim 21, wherein the separation system comprises an inertial separation system.

27. The system of claim 21, wherein the filtration system comprises a sintered ceramic filtration system, a sintered metal filtration system, a fabric bag filtration system, or a fluidized bed filtration system, or any combinations thereof.

28. The system of claim 21, wherein the separation system comprises a wet removal system, and wherein the wet removal system comprises a venturi scrubber, a counter current water scrubber, a steam condensation system, or a barometric condensation system, or any combinations thereof.

29. The system of claim 21, wherein the system is configured to combine the first purified stream and the second purified stream into a final purified stream of the carbon nanotubes.

30. The system of claim 21, comprising a second separation vessel configured to generate an additional purified stream of the carbon nanotubes and an additional residual stream comprising gaseous components from the gas flow or the first purified stream of the carbon nanotubes, or both.

CLAIMS

1. A system for producing carbon nanotubes, comprising:

a reactor to react a feed gas with catalyst particles to form carbon nanotube, the reactor to discharge a continuous reactor effluent comprising the carbon nanotubes and catalyst particles;

a first separation vessel to receive the continuous reactor effluent from the reactor and configured to:

isolate catalyst particles from the continuous reactor effluent; and

return the catalyst particles to the reactor via a recycle line coupling the first separation vessel to the reactor; and

a second separation vessel to receive the continuous reactor effluent from the first separation vessel and configured to:

isolate the carbon nanotubes from the continuous reactor effluent; and

generate a stream comprising gaseous components from the continuous reactor effluent.

2. The system of claim 1, comprising a heat exchanger to condense water in the stream, wherein the reactor comprises a fluidized bed reactor that is configured to accept the catalyst particles from the first separation vessel, and wherein the second separation vessel comprises a cyclonic separator having a swirl element to impart radial acceleration and a tangential velocity component to the continuous reactor effluent.

3. The system of claim 2, wherein the swirl element comprises swirl vanes that rotate to impart the radical acceleration and the tangential velocity component, wherein the heat exchanger comprises an ambient-temperature heat exchanger, and wherein the stream comprises residual carbon nanotubes.

4. The system of claim 1, wherein the reactor comprises an outlet on an upper portion of the reactor to discharge overhead from the reactor the continuous reactor effluent, and wherein the second separation vessel comprises a gravity separation vessel.

5. The system of claim 4, wherein the gravity separation vessel comprises a cyclonic separator comprising a single cyclone or multiple cyclones.

6. The system of claim 1, wherein the first separation vessel comprises a cyclonic separation vessel or a magnetic separation vessel.

7. The system of claim 1, comprising a heat exchanger to heat the feed gas with waste heat from the stream.

8. The system of claim 7, comprising a second heat exchanger to condense water in the stream.

9. The system of claim 1, wherein the second separation vessel comprises an electrostatic separation unit configured to impose an electric field.

10. The system of claim 1, wherein the second separation vessel comprises a magnetic separation vessel.

11. The system of claim 1, comprising a filter to remove residual carbon nanotubes from the stream.

12. The system of claim 11, wherein the filter comprises a sintered ceramic filter, a sintered metal filter, a fabric bag filter, or a fluidized bed filter, or any combinations thereof.

13. The system of claim 11, wherein the filter is configured to perform a self-cleaning procedure to remove carbon nanotubes.

14. A method for producing carbon nanotubes, comprising:

reacting a feed gas with catalyst particles in a reactor to form the carbon nanotubes;

discharging a continuous reactor effluent overhead from the reactor via an outlet on an upper portion of the reactor, the continuous reactor effluent comprising the carbon nanotubes and catalyst particles;

flowing the continuous reactor effluent through a catalyst separation vessel that removes the catalyst particles from the continuous reactor effluent, and returns the catalyst particles to the reactor via a recycle line coupling the catalyst separation vessel to the reactor;

flowing the continuous reactor effluent from the catalyst separation vessel to a carbon nanotube separation vessel; and

separating carbon nanotubes from the continuous reactor effluent in the carbon nanotube separation vessel, generating a stream comprising gaseous components from the continuous reactor effluent.

15. The method of claim 14, wherein separating the carbon nanotubes from the continuous reactor effluent in the carbon nanotube separation vessel comprises isolating the carbon nanotubes from the stream comprising gaseous components through an electromagnetic separation process.

16. The method of claim 14, wherein the catalyst separation vessel comprises a cyclonic separation vessel, and wherein separating the carbon nanotubes from the continuous reactor effluent in the carbon nanotube separation vessel comprises isolating the carbon nanotubes from the stream comprising gaseous components through a gravity separation process.

17. The method of claim 16, wherein the carbon nanotube separation vessel comprises a cyclonic separator, and further comprising imparting, via a swirl element of the cyclonic separator, a radial acceleration and a tangential velocity component to the continuous reactor effluent.

18. The method of claim 17, wherein the cyclonic separator comprises a multicyclonic separator.

19. The method of claim 14, wherein the carbon nanotube separation vessel separates the carbon nanotubes from the continuous reactor effluent, generating the stream comprising gaseous components through a density based separation process.

20. The method of claim 14, comprising:

filtering the stream to remove residual carbon nanotubes; and

condensing water in the stream via an ambient temperature heat exchanger.

21. A system for producing carbon nanotubes, comprising:

a reactor to react a feed gas with catalyst in a Bosch reaction to form carbon nanotubes, the reactor to discharge a continuous reactor effluent comprising the carbon nanotubes and catalyst;

a catalyst separator to separate catalyst from the continuous reactor effluent and return the catalyst to the reactor through a recycle line coupling the catalyst separator to the reactor;

a separation system to receive the continuous reactor effluent from the catalyst separator to isolate the carbon nanotubes from the continuous reactor effluent to generate a first purified stream of the carbon nanotubes and a first residual stream comprising gaseous components from the continuous reactor effluent; and

a filtration system configured to filter the first residual stream to generate a second purified stream of the carbon nanotubes and a second residual stream comprising the gaseous components.

22. The system of claim 21, wherein the separation system comprises a cyclonic separator having a swirl element to impart radial acceleration and a tangential velocity component to the continuous reactor effluent.

23. The system of claim 21, wherein the separation system comprises multicyclonic separation system or a single cyclonic separation system.

24. The system of claim 21, wherein the separation system comprises an electrostatic precipitator.

25. The system of claim 21, wherein the separation system comprises a magnetic separation system.

26. The system of claim 21, comprising an ambient temperature heat exchanger to condense water in the second residual stream, wherein the separation system comprises the catalyst separator.

27. The system of claim 21, wherein the filtration system comprises a sintered ceramic filtration system, a sintered metal filtration system, a fabric bag filtration system, or a fluidized bed filtration system, or any combinations thereof.

28. The system of claim 22, wherein the reactor comprises a fluidized bed reactor, and wherein the swirl element comprises swirl vanes that rotate to impart the radical acceleration and the tangential velocity component.

29. The system of claim 21, wherein the system is configured to combine the first purified stream and the second purified stream into a final purified stream of the carbon nanotubes.

30. The system of claim 21, comprising a heat exchanger to heat the feed gas with waste heat from the second residual stream, wherein the reactor comprises an outlet on an upper portion of the reactor to discharge overhead from the reactor the continuous reactor effluent.