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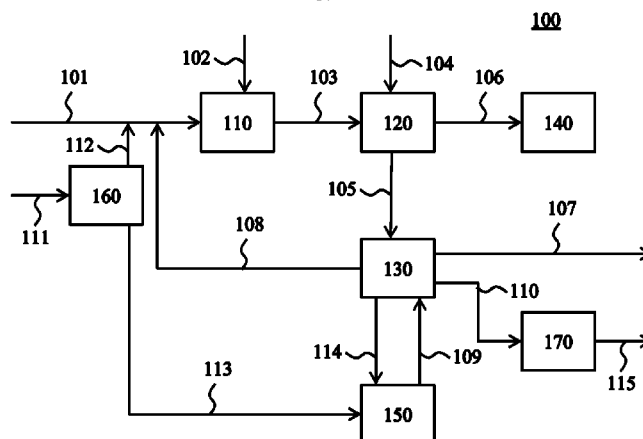
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FIG. 1



(57) Abstract: Systems and methods for producing C2 hydrocarbons and steam from the oxidative coupling of methane (OCM) are provided. Systems can include an OCM reactor coupled to at least two inlet streams and an effluent stream and a monolith coated with an alkali earth metal oxide catalyst within the OCM reactor. Systems can further include a cooling unit, coupled to the OCM reactor, for cooling the effluent stream and producing high pressure steam, a separations unit, coupled to the cooling unit, for separating C2 hydrocarbons from the effluent stream, and a generator, coupled to the cooling unit, for converting the high pressure steam to electricity. Methods can include introducing a methane stream to an alkali earth metal oxide catalyst in the presence of an oxidation agent to produce an effluent stream including C2 hydrocarbons and removing heat from the effluent stream and transferring the heat to produce high pressure steam.

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**SYSTEMS AND METHODS FOR PRODUCING C₂ HYDROCARBONS AND
STEAM FROM THE OXIDATIVE COUPLING OF METHANE**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of U.S. Provisional Application
5 No. 62/259,285, filed November 24, 2015. The contents of the referenced application are
incorporated into the present application by reference.

FIELD

[0002] The disclosed subject matter relates to systems and methods for producing C₂
hydrocarbons and steam from the oxidative coupling of methane.

BACKGROUND

[0003] Cracking processes are used in the petrochemical industry to produce useful
chemical intermediates from higher hydrocarbons, *e.g.*, natural gas and petroleum distillates.
For example, ethylene, a precursor to many plastic polymers including polyethylene,
polyvinyl chloride, polystyrene, and polyvinyl acetate, can be made by the steam cracking of
15 hydrocarbons, including ethane. Steam cracking involves thermal cracking, followed by
quenching and fractionation, and can therefore be energy intensive.

[0004] Methane can be used as an alternate feedstock to produce ethylene. Methane,
which is a main component of natural gas, is widely used as fuel and as a starting material for
chemical processes, *e.g.*, steam reforming to produce syngas. Additionally, methane can
20 undergo oxidative coupling to form ethane and ethylene. The oxidative coupling of methane
is highly exothermic, and therefore there is interest in integrating the reaction with heat
recovery, for example by using the heat to produce steam.

[0005] Certain methods for recovering heat from the oxidative coupling of methane are
known in the art. For example, U.S. Patent Publication No. 2014/0018589 discloses a system
25 for the oxidative coupling of methane that includes converting the thermal energy produced

by the reaction into steam. U.S. Patent Publication No. 2014/0012053 discloses a system for processing natural gas including a reactor for the oxidative coupling of methane. The reactor can be integrated into an existing natural gas processing system, *e.g.*, by using an existing separation system to separate the product stream from the reactor. Additionally, the system
5 can include a steam generator for recovering heat from the reactor.

[0006] U.S. Patent Publication No. 2015/0210610 discloses a system for the oxidative coupling of methane that includes a reactor for producing C₂ hydrocarbons, and a subsystem for converting the heat from the reactor into electrical power. U.S. Patent Publication No. 2010/0249473 discloses a process for the oxidative coupling of hydrocarbons, such as
10 methane, which includes an oxidative coupling reaction and recovering heat from the reaction for use as steam in an existing ethylene operation.

[0007] However, there remains a need for improved techniques for producing C₂ hydrocarbons and steam from the oxidative coupling of methane. The present disclosure addresses these and other needs.

SUMMARY OF THE DISCLOSED SUBJECT MATTER

[0008] The disclosed subject matter provides systems and methods for producing C₂ hydrocarbons and steam from methane. Particularly, the disclosed systems and methods provide for the oxidative coupling of methane to produce C₂ hydrocarbons, *e.g.*, ethane and ethylene, and cooling those products to produce high pressure steam.

[0009] In certain embodiments, an exemplary system for the oxidative coupling of methane (OCM) includes an OCM reactor coupled to at least two inlet streams and an effluent stream, wherein a first inlet stream includes methane and a second inlet stream includes an oxidation agent, and a monolith within the OCM reactor, wherein the monolith is coated with an alkali earth metal oxide catalyst. An exemplary system can further include a
20 cooling unit, coupled to the OCM reactor, for cooling the effluent stream and producing high
25

pressure steam, a separations unit, coupled to the cooling unit, for separating C₂ hydrocarbons from the effluent stream, and a generator, coupled to the cooling unit, for converting the high pressure steam to electricity.

[0010] In certain embodiments, the oxidation agent can include oxygen and/or air. The alkali earth metal oxide catalyst can include an alkali earth metal oxide, such as BeO, MgO, CaO, SrO, BaO, and combinations thereof. The alkali earth metal oxide catalyst can further include a metal oxide, such as CaO, TiO₂, ThO₂, SiO₂, Sm₂O₃, and combinations thereof. In certain embodiments, the alkali earth metal oxide catalyst can be a mixture of CaO, MgO, and Sm₂O₃.

[0011] In certain embodiments, the monolith has channels having diameters less than about 4mm. The monolith can have channels with diameters less than about 1mm. The OCM reactor can be a quartz reactor having a diameter of about 1 inch. The OCM reactor can have a temperature of about 1000°C.

[0012] In certain embodiments, the system can include a recycle stream, coupled to the separations unit and the OCM reactor, for transferring methane from the separations unit to the OCM reactor. The system can further include a steam cracking unit, coupled to the separations unit, for converting ethane to ethylene. The system can include a natural gas feed stream and a natural gas separations unit, coupled to the feed stream, for separating the natural gas into the first inlet stream containing methane and an ethane stream. The ethane stream can be coupled to the steam cracking unit for transferring ethane to the steam cracking unit. The system can further include a hydrogenation unit, coupled to the separations unit, for converting a carbon dioxide stream from the separations unit into a syngas stream.

[0013] In other certain embodiments, an exemplary system for the oxidative coupling of methane (OCM) can include an OCM reactor coupled to at least two inlet streams and an effluent stream, wherein a first inlet stream includes methane and a second inlet stream

includes an oxidation agent, and catalyst pellets including CaO, MgO, and Sm₂O₃ within the OCM reactor. An exemplary system can further include a cooling unit, coupled to the OCM reactor, for cooling the effluent stream and producing high pressure steam, a separations unit, coupled to the cooling unit, for separating C₂ hydrocarbons from the effluent stream, and a generator, coupled to the cooling unit, for converting the high pressure steam to electricity.

[0014] The disclosed subject matter further provides methods for producing C₂ hydrocarbons and steam from methane by the oxidative coupling of methane. An exemplary method for the oxidative coupling of methane can include introducing a methane stream to an alkali earth metal oxide catalyst in the presence of an oxidation agent to produce an effluent stream including C₂ hydrocarbons and removing heat from the effluent stream and transferring the heat to a water stream to produce high pressure steam.

[0015] In certain embodiments, the method can further include separating the effluent stream into a first stream including ethylene, a second stream including methane, a third stream including ethane, and a fourth stream including carbon dioxide. The second stream can be recycled by combining it with the methane stream. The third stream can undergo steam cracking. The fourth stream can be hydrogenated to produce syngas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 depicts a system for producing C₂ hydrocarbons and steam from methane according to one exemplary embodiment of the disclosed subject matter.

[0017] FIG. 2 depicts a method of producing C₂ hydrocarbons and steam from methane according to one exemplary embodiment of the disclosed subject matter.

DETAILED DESCRIPTION

[0018] The presently disclosed subject matter provides novel systems and methods for producing C₂ hydrocarbons and steam from methane. Particularly, the disclosed systems and methods provide for the oxidative coupling of methane to produce C₂ hydrocarbons, *e.g.*,

ethane and ethylene, and cooling the C₂ hydrocarbons to produce high pressure steam.

[0019] “Coupled” as used herein refers to the connection of a system component to another system component by any suitable means known in the art. The type of coupling used to connect two or more system components can depend on the scale and operability of the system. For example, and not by way of limitation, coupling of two or more components of a system can include one or more joints, valves, transfer lines or sealing elements. Non-limiting examples of joints include threaded joints, soldered joints, welded joints, compression joints and mechanical joints. Non-limiting examples of fittings include coupling fittings, reducing coupling fittings, union fittings, tee fittings, cross fittings and flange fittings. Non-limiting examples of valves include gate valves, globe valves, ball valves, butterfly valves and check valves.

[0020] As used herein, the term “about” or “approximately” means within an acceptable error range for the particular value as determined by one of ordinary skill in the art, which will depend in part on how the value is measured or determined, *i.e.*, the limitations of the measurement system. For example, “about” can mean a range of up to 20%, up to 10%, up to 5%, and or up to 1% of a given value.

Systems for Producing C₂ Hydrocarbons and Steam from Methane

[0021] The disclosed subject matter provides systems for producing C₂ hydrocarbons and steam from methane by the oxidative coupling of methane (OCM). For the purpose of illustration and not limitation, FIG. 1 is a schematic representation of a system according to a non-limiting embodiment of the disclosed subject matter. The system can include an OCM reactor 110, coupled to one or more inlet streams 101, 102 and an effluent stream 103, a cooling unit 104 coupled to the OCM reactor, a separations unit 130 coupled to the cooling unit, and a generator 140 coupled to the cooling unit.

[0022] The oxidative coupling of methane can convert methane, either in the form of

natural gas or purified methane, to other chemicals, notably C₂ hydrocarbons, *e.g.*, ethylene (C₂H₄) and ethane (C₂H₆). The side reactions of the oxidative coupling of methane can form carbon monoxide (CO) and/or carbon dioxide (CO₂). The oxidative coupling of methane and its side reactions are illustrated by the following formulas:



[0023] The oxidative coupling of methane and its side reactions are exothermic and
10 produce large amounts of heat. Additionally, the reaction must be carried out at high
temperatures, *e.g.*, greater than about 750°C, to activate the methane. Methane is activated to
form methyl free radicals, which couple to produce ethane (Formula 2), which can then be
dehydrogenated to form ethylene (Formula 1). However, the methyl free radicals can also
react with oxygen to form CO and CO₂ in side reactions (Formulas 3 and 4).

15 **[0024]** In certain embodiments, the oxidative coupling of methane is performed in an
OCM reactor 110. The OCM reactor can be coupled to one or more inlet streams 101, 102
and an effluent stream 103. In certain embodiments, a first inlet stream 101 can transfer
methane to the OCM reactor. The methane of the presently disclosed subject matter can
originate from various sources. For example, the methane can come from natural gas or as a
20 gaseous stream from other chemical processes. In certain embodiments, the first inlet stream
can transfer a natural gas stream containing methane to the OCM reactor. In other certain
embodiments, the first inlet stream can transfer a purified methane stream to the OCM
reactor. For example, the amount of methane in a purified methane stream can be greater
than about 80%, greater than about 85%, greater than about 90%, greater than about 95%, or
25 greater than about 99%.

[0025] In certain embodiments, a second inlet stream 102 can transfer an oxidation agent to the OCM reactor. The oxidation agent for use in the presently disclosed subject matter can include oxygen, *e.g.*, as purified oxygen or air. In certain embodiments, the oxidation agent is air. In certain embodiments, the first and second inlet streams can be combined prior to
5 transfer to the OCM reactor.

[0026] The methane and oxidation agent can be transferred to the OCM reactor in a certain flow ratio. For example, methane and oxygen (present in the oxidation agent) can have a flow ratio ($\text{CH}_4:\text{O}_2$) of about 5:1, about 4:1, about 3:1, about 2:1, about 1:1, about 0.5:1, about 0.4:1, about 0.3:1, about 0.2:1, about 0.1:1. In certain embodiments, the flow
10 ratio ($\text{CH}_4:\text{O}_2$) is about 3:1. In certain embodiments, the total flow rate of methane and the oxidation agent can be from about 300 cc/min to about 1000 cc/min, from about 350 cc/min to about 950 cc/min, or from about 400 cc/min to about 900 cc/min. In certain embodiments, the total flow rate is about 420 cc/min. In other certain embodiments, the total flow rate is about 840 cc/min.

[0027] The OCM reactor 110 can be any reactor type known to be suitable for the oxidative coupling of methane. For example, but not by way of limitation, such reactors include plug flow reactors, fixed bed reactors, such as tubular fixed bed reactors and multi-tubular fixed bed reactors, and fluidized bed reactors, such as entrained fluidized bed reactors and fixed fluidized bed reactors. The reactor can be made of any suitable material, including
15 but not limited to, quartz, ceramic materials, glass-lined materials, polymer-based materials, carbon steel, aluminum, stainless steel, nickel-base metal alloys, cobalt-based metal alloys, or combinations thereof. In certain embodiments, the OCM reactor is a quartz reactor.

[0028] The dimensions and structure of the OCM reactor 110 can vary depending on its capacity, which can be determined by the reaction rate, the stoichiometric quantities of the
20 reactants and/or the feed flow rate. The space velocity of the reaction can range from about

1000 h⁻¹ to about 10,000 h⁻¹, from about 2500 h⁻¹ to about 8500 h⁻¹, or from about 3500 h⁻¹ to about 7500 h⁻¹. In certain embodiments, the space velocity of the reaction is about 3600 h⁻¹. In certain other embodiments, the space velocity of the reaction is about 7200 h⁻¹. In certain embodiments, the OCM reactor is a tubular reactor having a diameter of about 1 inch.

5 [0029] The OCM reactor 110 can be operated isothermally. For example, the OCM reactor can be maintained at a temperature from about 600°C to about 1200°C, from about 700°C to about 1000°C, or from about 750°C to about 900°C. In particular embodiments, the OCM reactor can be maintained at a temperature from about 750°C to about 820°C.

[0030] In certain embodiments, the OCM reactor 110 can contain a catalyst. The catalyst
10 can include an alkali earth metal oxide. For example, the catalyst can include BeO, MgO, CaO, SrO, BaO, CeO₂ and/or combinations thereof. The catalyst can further include another metal oxide. For example, the catalyst can further include CaO, TiO₂, ThO₂, SiO₂, SmO₂, La₂O₃, and/or combinations thereof. In certain embodiments, the catalyst is a combination of CeO₂ and La₂O₃. In certain other embodiments, the catalyst is a combination of CaO, MgO,
15 and La₂O₃. In certain other embodiments, the catalyst is a combination of CaO, MgO, and Sm₂O₃.

[0031] Catalyst loading in the OCM reactor 110 can range from about 2 mL to about 15 mL, from about 4 mL to about 12 mL, or from about 5 mL to about 10 mL. In certain embodiments, catalyst loading is about 7 mL.

20 [0032] In certain embodiments, the catalyst can be supported on a monolith. The monolith can be made of any suitable material, including but not limited to ceramic materials. The monolith can include channels. The channels may be round or polygonal, *e.g.*, triangular, quadrilateral, pentagonal, or hexagonal. In certain embodiments, the channels are round, and can have diameters less than about 4mm, less than about 2mm, or less than about
25 1mm. In particular embodiments, the channels have diameters of about 1mm.

[0033] In other certain embodiments, the catalyst can be supported on pellets. The pellets can contain a porous material having pore diameters of about 2nm to about 100nm. For example, the pellets can be made of alumina (Al_2O_3), silica (SiO_2), titania (TiO_2), zirconia (ZrO_2), chromium (III) oxide (Cr_2O_3), magnesia (MgO), cerium (IV) oxide (CeO_2) and/or combinations thereof. The pellets can have a particle size from about 20 to about 50 mesh.

[0034] The OCM reactor 110 can be coupled to a cooling unit 120, *i.e.*, via the effluent stream 103. In certain embodiments, the cooling unit 120 can include one or more steam generators, one or more boilers, one or more evaporators, and/or one or more heat exchangers to produce high pressure steam using the heat from the effluent stream. The cooling unit can be coupled to a feed line 104 for providing water or steam.

[0035] The cooling unit 120 can produce a cooled effluent stream 105 and a high pressure steam stream 106. In certain embodiments, the high pressure steam stream can be coupled to a generator 140 for converting the high pressure steam to electricity. For example the generator can include a steam turbine to drive the generator. Alternatively, high pressure steam can be used to provide mechanical drive, *e.g.*, to one or more pumps or compressors, or to provide thermal energy, *e.g.*, to other streams via a heat exchanger.

[0036] In certain embodiments, the system 100 can further include a separations unit 130, coupled to the cooling unit 120, for separating C_2 hydrocarbons from the cooled effluent stream 106. The effluent stream can contain C_2 hydrocarbons, *e.g.*, ethylene and ethane. In certain embodiments, the effluent stream can contain less than about 10 wt-%, less than about 7 wt-%, or less than about 5 wt-% C_2 hydrocarbons. The effluent stream can further include carbon monoxide, carbon dioxide, and unconverted methane. Because of the low amount of C_2 hydrocarbons in the effluent stream, it can be desirable to combine the effluent stream with another stream to increase the amount of C_2 hydrocarbons and make separation easier and less expensive. For example, the oxidative coupling of methane described above can be

integrated with an ethane steam cracking operation. The cooled effluent stream 106 from the oxidative coupling of methane can be separated with the cracking product stream 109 of an ethane steam cracking unit 150 by transferring it to the separations unit 130 of the ethane steam cracking operation.

5 [0037] The ethane steam cracking unit 150 for use in certain embodiments of the disclosed subject matter can include a furnace, also known as a fired heater. The furnace can include a radiant section having one or more burners and a convection section. The furnace can further include one or more catalyst tubes and/or tubular reactors. Ethane can be provided to the ethane steam cracking unit via an ethane stream 113 coupled to the ethane
10 steam cracking unit. A cracking products stream 109 can be coupled to the ethane steam cracking unit for transferring cracking products, *e.g.*, ethylene and unconverted ethane, to the separations unit 130.

[0038] The separations unit 130 of the presently disclosed subject matter can include one or more distillation columns, which can be adapted to perform fractional distillation, vacuum
15 distillation, azeotropic distillation, extractive distillation, reactive distillation and/or steam distillation. The distillation columns can be adapted to continuous or batch distillation. The one or more distillation columns can be coupled to one or more condensers and one or more reboilers. The one or more distillation columns can be stage or packed columns, and can include plates, trays and/or packing material.

20 [0039] For example, the separations unit 130 can include a demethanizer for removing methane from the effluent stream 106 and the cracking product stream 109. Methane can be transferred via a recycle stream 108 to the OCM reactor 110. In certain embodiments, the recycle stream 108 can be combined with the first inlet stream 101 to the OCM reactor.

[0040] Additionally or alternatively, the separations unit 130 can include a C₂ splitter for
25 separating the effluent stream 106 and cracking product stream 109 into an ethane recycle

stream 114 and an ethylene product stream 107. The ethane recycle stream can transfer recovered ethane to the ethane steam cracking unit 150.

[0041] In certain embodiments, the separations unit 130 can be configured to recover side reaction products, *e.g.*, carbon monoxide and carbon dioxide, from the effluent stream 106.

5 For example, CO₂ can be removed from the effluent stream by an acid gas removal process. A CO₂ stream 110 can be coupled to the separations unit for removing CO₂ from the separations unit.

[0042] In certain embodiments, the CO₂ stream 110 can be further coupled to a hydrogenation unit 170 for producing a syngas stream 115. Syngas can be produced by the
10 hydrogenation of carbon dioxide. For example, carbon dioxide (CO₂) and hydrogen (H₂) can react to form carbon monoxide (CO) and water (H₂O) in a reverse water gas shift reaction. The reverse water gas shift reaction is illustrated by:



[0043] The reverse water gas shift reaction is equilibrium-driven, and can be performed
15 under conditions resulting in only partial conversion of CO₂ and H₂. Thus, the hydrogenation of carbon dioxide by the reverse water gas shift reaction can result in a syngas stream containing CO₂ and H₂, as well as CO and H₂O.

[0044] The ratio of H₂ and CO in the syngas stream 115 can be significant in downstream reactions and can be manipulated by varying process conditions, *e.g.*, reaction conditions,
20 catalyst type or amount, or the ratio of CO₂ to H₂ provided to the hydrogenation unit 170. In certain embodiments, H₂ can be provided to the hydrogenation unit via a hydrogen stream. The flow of the hydrogen stream can be adjusted to be stoichiometrically less than the flow of CO₂. The resulting syngas stream 115 can have a molar ratio of H₂ to CO of about 2:1.

[0045] In certain embodiments, the system 100 can further include a natural gas
25 separations unit 160 for separating a feed stream 111 containing natural gas into a methane

feed stream 112 and an ethane feed stream 113. The natural gas separations unit can include a distillation column, which can be adapted to separating ethane from methane, *e.g.*, by fractional distillation. The methane feed stream 112 can transfer methane to the OCM reactor. In certain embodiments, the methane feed stream can be combined with the first inlet stream 101 and/or the methane recycle stream 108. The ethane feed stream 113 can transfer ethane to the ethane steam cracking unit 150. In certain embodiments, the ethane feed stream can be combined with the ethane recycle stream 114.

[0046] The presently disclosed systems can further include additional components and accessories including, but not limited to, one or more gas exhaust lines, cyclones, product discharge lines, reaction zones, heating elements and one or more measurement accessories. The one or more measurement accessories can be any suitable measurement accessory known to one of ordinary skill in the art including, but not limited to, pH meters, flow monitors, pressure indicators, pressure transmitters, thermowells, temperature-indicating controllers, gas detectors, analyzers and viscometers. The components and accessories can be placed at various locations within the system.

Methods for Producing C₂ Hydrocarbons and Steam from Methane

[0047] The presently disclosed subject matter further provides methods for producing C₂ hydrocarbons and steam from methane, particularly by the oxidative coupling of methane. For the purpose of illustration and not limitation, FIG. 2 is a schematic representation of a method according to a non-limiting embodiment of the disclosed subject matter.

[0048] The method 200 can include introducing a methane stream to an alkali earth metal oxide catalyst in the presence of an oxidation agent to produce an effluent stream including C₂ hydrocarbons 201 and removing heat from the effluent stream and transferring the heat to a water stream to produce high pressure steam 202.

[0049] In certain embodiments, the methane stream can include natural gas or purified

methane, as described above. For example, the amount of methane in a purified methane stream can be greater than about 80%, greater than about 85%, greater than about 90%, greater than about 95%, or greater than about 99%.

[0050] The methane stream can undergo oxidative coupling to produce the effluent stream. The conversion of methane in the methane stream can be from about 10% to about 40%, from about 15% to about 35%, or from about 20% to about 30%. In certain embodiments, the conversion of methane is about 25%. The oxidative coupling of methane can have a certain selectivity to C₂ hydrocarbons. In certain embodiments, the selectivity to C₂ hydrocarbons is about 60%.

[0051] In certain embodiments, the method 200 can further include separating the effluent stream into a first stream including ethylene, a second stream including methane, a third stream including ethane, and a fourth stream including carbon dioxide 203. The second stream can be recycled by combining it with the methane stream 204.

[0052] In certain embodiments, the third stream including ethane can undergo stream cracking 205. The steam cracking can produce a cracking products stream containing ethylene and unconverted ethane. The unconverted ethane can be separated and recycled to the steam cracking process. In certain embodiments, the cracking products stream can be combined with the effluent stream from the oxidative coupling of methane prior to separating the streams into ethylene, ethane, methane, and carbon dioxide.

[0053] In certain embodiments, the fourth stream including carbon dioxide can be hydrogenated to produce a syngas stream 206. For example, carbon dioxide can undergo the reverse water gas shift reaction (Formula 5) to produce a syngas stream containing carbon monoxide, water, carbon dioxide, and/or water.

[0054] The systems and methods of the presently disclosed subject matter provide advantages over certain existing technologies. Exemplary advantages include improved

production of ethylene using alkali earth metal oxide catalysts, efficient heat recovery to produce high pressure steam, and integrating the oxidative coupling of methane into an ethane steam cracking process.

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* * *

[0055] In addition to the various embodiments depicted and claimed, the disclosed subject matter is also directed to other embodiments having other combinations of the features disclosed and claimed herein. As such, the particular features presented herein can be combined with each other in other manners within the scope of the disclosed subject matter such that the disclosed subject matter includes any suitable combination of the features disclosed herein. The foregoing description of specific embodiments of the disclosed subject matter has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosed subject matter to those embodiments disclosed.

10
15 [0056] It will be apparent to those skilled in the art that various modifications and variations can be made in the systems and methods of the disclosed subject matter without departing from the spirit or scope of the disclosed subject matter. Thus, it is intended that the disclosed subject matter include modifications and variations that are within the scope of the appended claims and their equivalents.

CLAIMS

1. A system for oxidative coupling of methane (OCM), comprising:
 - (a) an OCM reactor coupled to at least two inlet streams and an effluent stream, wherein a first inlet stream comprises methane and a second inlet stream comprises an oxidation agent;
 - (b) a monolith within the OCM reactor, wherein the monolith is coated with an alkali earth metal oxide catalyst;
 - (c) a cooling unit, coupled to the OCM reactor, for cooling the effluent stream and producing high pressure steam;
 - (d) a separations unit, coupled to the cooling unit, for separating C₂ hydrocarbons from the effluent stream; and
 - (e) a generator, coupled to the cooling unit, for converting the high pressure steam to electricity.
2. The system of claim 1, wherein the oxidation agent comprises oxygen or air.
3. The system of claim 1, wherein the oxidation agent is air.
4. The system of claim 1, wherein the alkali earth metal oxide catalyst comprises an alkali earth metal oxide selected from the group consisting of BeO, MgO, CaO, SrO, BaO, CeO₂, and combinations thereof.
5. The system of claim 4, wherein the alkali earth metal oxide catalyst further comprises a metal oxide selected from the group consisting of CaO, TiO₂, ThO₂, SiO₂, Sm₂O₃, La₂O₃, and combinations thereof.
6. The system of claim 1, wherein the alkali earth metal oxide catalyst comprises a mixture of CaO, MgO, and Sm₂O₃.
7. The system of claim 1, wherein the alkali earth metal oxide comprises a mixture of CaO, MgO, and La₂O₃.

8. The system of claim 1, wherein the alkali earth metal oxide comprises a mixture of CeO_2 and La_2O_3 .
9. The system of claim 1, wherein the monolith has channels having diameters less than about 4mm.
10. The system of claim 9, wherein the channels have diameters less than about 1mm.
11. The system of claim 1, wherein the OCM reactor is a quartz reactor having a diameter of about 1 inch.
12. The system of claim 1, wherein the OCM reactor has a temperature from about 750°C to about 900°C .
13. The system of claim 1, further comprising a recycle stream, coupled to the separations unit and the OCM reactor, for transferring methane from the separations unit to the OCM reactor.
14. The system of claim 1, further comprising a steam cracking unit, coupled to the separations unit, for converting ethane to ethylene.
15. The system of claim 14, further comprising:
 - (a) a feed stream comprising natural gas; and
 - (b) a natural gas separations unit, coupled to the feed stream, for separating the natural gas into the first inlet stream and an ethane stream, wherein the ethane stream is coupled to the steam cracking unit for transferring ethane to the steam cracking unit.
16. The system of claim 1, further comprising a hydrogenation unit, coupled to the separations unit, for converting a carbon dioxide stream from the separations unit into a syngas stream.
17. A system for oxidative coupling of methane (OCM), comprising:
 - (a) an OCM reactor coupled to at least two inlet streams and an effluent stream,

- wherein a first inlet stream comprises methane and a second inlet stream comprises an oxidation agent;
- (b) catalyst pellets comprising CaO, MgO, and Sm₂O₃ within the OCM reactor;
 - (c) a cooling unit, coupled to the OCM reactor, for cooling the effluent stream and producing high pressure steam;
 - (d) a separations unit, coupled to the cooling unit, for separating C₂ hydrocarbons from the effluent stream; and
 - (e) a generator, coupled to the cooling unit, for converting the high pressure steam to electricity.
18. A method for oxidative coupling of methane, comprising:
- (a) introducing a methane stream to an alkali earth metal oxide catalyst in the presence of an oxidation agent to produce an effluent stream comprising C₂ hydrocarbons; and
 - (b) removing heat from the effluent stream and transferring the heat to a water stream to produce high pressure steam.
19. The method of claim 18, further comprising separating the effluent stream into a first stream comprising ethylene, a second stream comprising methane, a third stream comprising ethane, and a fourth stream comprising carbon dioxide.
20. The method of claim 19, further comprising (i) recycling the second stream by combining it with the methane stream, (ii) steam cracking the third stream, (iii) hydrogenating the fourth stream to produce syngas, or any combination thereof or all of (i) to (iii).

FIG. 1

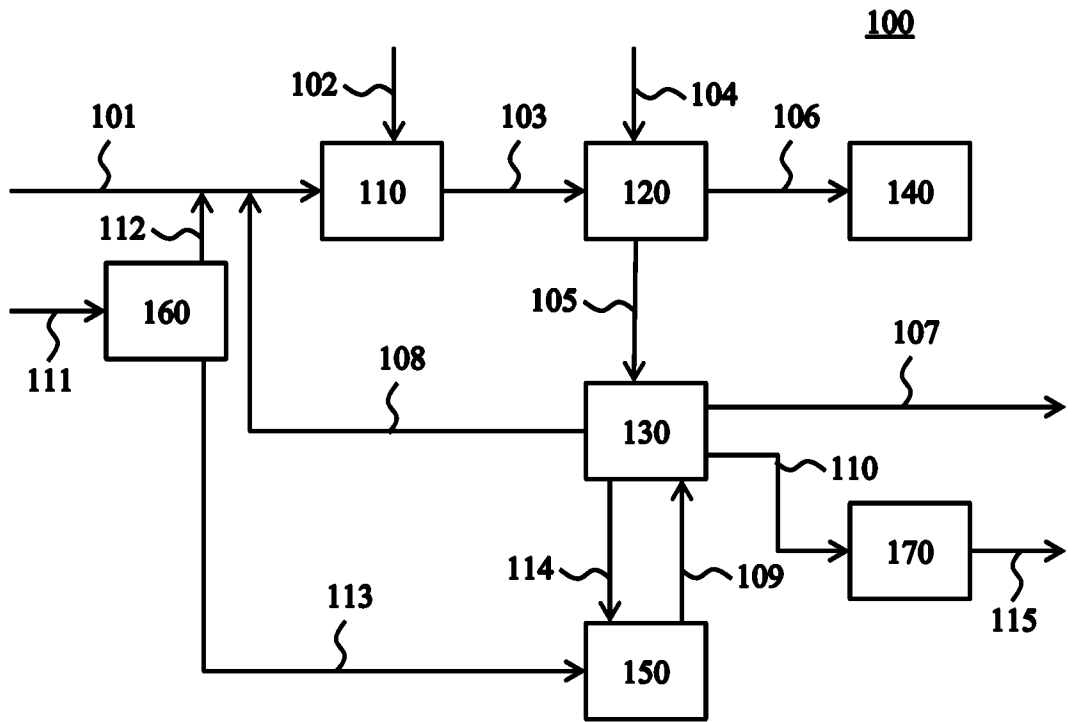


FIG. 2

