

ENHANCED HOMOGENOUS CATALYZED REACTOR SYSTEMS

TECHNICAL FIELD

[0001] The presently disclosed subject matter relates to reactors and methods for performing gas/liquid chemical reactions.

BACKGROUND

[0002] Gas/liquid chemical and biochemical reactions catalyzed by homogenous catalysts can be conducted in certain conventional reactor systems, including plug flow reactors (PFRs), continuously stirred tank reactors (CSTRs), and bubble column reactors (BCRs). However, PFRs can have limited heat removal, which in turn demands high flowrate. CSTRs can have low selectivity and reactor fouling. CSTRs can have relatively broad residence time distributions, which can lead to relatively high concentrations of impurities, which can be difficult to remove. BCRs can have undefined flow patterns within the reactor and non-uniform mixing, which can cause low selectivity and difficulties in scale-up.

[0003] Thus, there remains a need in the art for improved reactors and methods for homogenous catalyzed reactions with improved properties, including mixing, removal of heat, efficiency, and selectivity.

SUMMARY

[0004] Disclosed, in various embodiments, are reactors and methods for performing a process.

[0005] A reactor for performing processes for a product line comprises: a reaction vessel adapted to be coupled to the product line; a gas sparger adapted to be coupled to a gas feed line; and a liquid distributor proximate a top of the reaction vessel and adapted to be coupled to a liquid feed line.

[0006] A method of performing a process comprises: providing a reactor comprising a reaction vessel; introducing a gas to the reaction vessel through a gas sparger coupled to the reaction vessel and a gas feed line; introducing a liquid to the reaction vessel through a liquid distributor proximate a top of the reaction vessel and coupled to a liquid feed line; performing a reaction in the reaction vessel; and removing a product from the reaction vessel through a product line coupled to the reaction vessel.

[0007] These and other features and characteristics are more particularly described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The following is a brief description of the drawings wherein like elements are numbered alike and which are presented for the purposes of illustrating the exemplary embodiments disclosed herein and not for the purposes of limiting the same.

[0009] FIG. 1 is a schematic diagram depicting an exemplary reactor in accordance with one nonlimiting embodiment of the disclosed subject matter.

[0010] FIG. 2A is a schematic diagram depicting another exemplary reactor in accordance with one nonlimiting exemplary embodiment of the disclosed subject matter.

[0011] FIG. 2B is a schematic diagram further illustrating the reactor of FIG. 2A.

DETAILED DESCRIPTION

[0012] The presently disclosed subject matter provides reactors and methods for performing gas/liquid chemical reactions.

[0013] The presently disclosed subject matter provides reactors and methods for performing processes, including, but not limited to, homogenous catalytic gas/liquid chemical reactions. In one embodiment, an exemplary reactor for performing processes for a product line can include a reaction vessel adapted to be coupled to a product line. The reactor can also include a gas sparger adapted to be coupled to a gas feed line and a liquid distributor proximate the top of the reaction vessel. The liquid distributor can be adapted to be coupled to a liquid feed line.

[0014] In certain embodiments of the disclosed subject matter, the gas sparger can be configured to permit introduction of a gas through a plurality (e.g., greater than 1) of locations along the sides of the reactor. Additionally or alternatively, the gas sparger can be proximate the bottom of the reaction vessel.

[0015] In certain embodiments of the disclosed subject matter, the reactor can further include an agitator. The agitator can be proximate the bottom of the reaction vessel.

[0016] In certain embodiments of the disclosed subject matter, a catalyst preformation system can be coupled to the liquid feed line. The catalyst preformation system can be configured to dose one or more catalyst solutions.

[0017] In certain embodiments of the disclosed subject matter, the reactor can further include a demister proximate the top of the reaction vessel. The demister can include a removable demister.

[0018] In certain embodiments of the disclosed subject matter, the reactor can further include a jacket configured to circulate a heating or cooling medium therearound. The jacket can be configured to provide heat or to remove heat from the reaction vessel.

[0019] In certain embodiments of the disclosed subject matter, the product line can be coupled to a separation system. The separation system can be configured to purify a desired product.

[0020] In certain embodiments of the disclosed subject matter, the reactor can further include thermocouples at a plurality of locations on the reactor.

[0021] In certain embodiments of the disclosed subject matter, the reaction vessel can further include a sight glass. The sight glass can be configured for monitoring the reaction vessel, including monitoring a reaction performed in the reactor, monitoring a dosing fed to the reactor, monitoring a mixing pattern in the reactor, and/or monitoring a product property in the reactor.

[0022] In certain embodiments of the disclosed subject matter, the reactor can be configured to perform oligomerization reactions. For example, the reactor can be configured to perform the oligomerization of ethylene to one or more of 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing.

[0023] In certain embodiments of the disclosed subject matter, the reactor does not include a cooling coil.

[0024] The presently disclosed subject matter can also provide methods of performing processes, including, but not limited to, homogenous catalytic gas/liquid chemical reactions. In one embodiment, an exemplary method of performing a process can include providing a reactor including a reaction vessel. The method can also include introducing a gas to the reaction vessel through a gas sparger coupled to the reaction vessel and a gas feed line. The method can also include introducing a liquid to the reaction vessel through a liquid distributor proximate a top of the reaction vessel and coupled to a liquid feed line. The method can also include performing a reaction in the reaction vessel. The method also includes removing a product from the reaction vessel through a product line coupled to the reaction vessel.

[0025] In certain embodiments of the disclosed subject matter, the process can be a homogenous catalytic process. In certain embodiments of the disclosed subject matter, the reaction can include one or more oligomerization reaction(s). For example, the

oligomerization reaction(s) can include oligomerization to one or more of ethylene to 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing. The product can include one or more of 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing.

[0026] For the purpose of illustration and not limitation, Figures 1, 2A, and 2B are schematic representations of an exemplary reactor according to the disclosed subject matter. The reactor 100, 200 can include a reaction assembly or vessel 101, 201 having a reaction chamber 102, 202 therein. The reactor 100, 200 can be constructed of any desirable materials such as, including, but not limited to, metals, alloys including steel, glass, enamels, ceramics, polymers, plastics, or a combination comprising at least one of the foregoing. The reactor 100, 200, reaction vessel 101, 201, and chamber 102, 202 can be any desired design or shape such as, including, but not limited to, tubular, cylindrical (as shown in Figures 1, 2A, and 2B), rectangular, dome, or bell shaped. The dimensions and size of the reactor 100, 200, reaction vessel 101, 201, and chamber 102, 202 can depend on the desired reaction type, production capacity, feed type, and any catalyst for which the reactor is intended. For example, the reaction vessel size can be about 50 milliliters (mL) (*e.g.*, for lab reactors) to about 20,000 Liters (L) (*e.g.*, for commercial reactors). The height-to-width ratio of the reaction vessel 101, 201 can vary. For example, the height-to-width ratio of the reactor 100, 200 and reaction vessel 101, 201 can be about 0.5:1 to about 10:1. In certain embodiments where the reactor 100, 200 and reaction vessel 101, 201 are cylindrical, the height-to-width ratio can also be expressed as a height to diameter ratio. The geometries of the reactor 100, 200, the reaction vessel 101, 201, and the chamber 102, 202 can be adjusted in various ways.

[0027] The reactor 100, 200 can include an agitator 103, and/or one or more impellers 104, and/or one or more baffles 105. The reactor 100, 200 can include one or more sample ports. The agitator, impeller(s), and baffle(s) can be made of any desirable materials and arranged in any desired configuration. For example, the agitator 103 can be a paddle agitator, an anchor agitator, a propeller agitator, a radial propeller agitator, a turbine agitator, or a helical agitator. The agitator 103 can be connected via a shaft to the impeller(s) 104. More than one impeller 104 can be connected to the agitator 103 at different locations along the agitator 103. The agitator 103 can be proximate the bottom of the reaction vessel. For example, the agitator 103 can be located at the bottom or within about 10% to about 25% of the distance from the bottom of the reaction vessel to the top of the reaction vessel 101. The impeller(s) 104 can be single-bladed, double-bladed, or any other desirable impeller(s). The baffle(s) 105 can take the form of a wall-mounted device or other suitable configurations

known to one of ordinary skill in the art, such as a longitudinal flow baffle, an orifice baffle, a single segmental baffle, or a double segmental baffle. The baffle(s) can promote mixing and improve heat transfer in the reactor.

[0028] The reactor 100, 200 can include both an agitator 103 and a gas sparger 106, 206. The gas sparger 106, 206 can be configured to permit introduction of a gas through a plurality of locations along the sides of the reactor. Additionally or alternatively, the gas sparger 106, 206 can be proximate the bottom of the reaction vessel to introduce gas from the bottom of the reactor. For example, the gas sparger 106, 206 can be located at the bottom or within about 10% to about 25% of the distance from the bottom of the reaction vessel 101, 201 to the top of the reaction vessel 101, 201.

[0029] The gas sparger 106, 206 can be adapted to be coupled to a gas feed line 111, 211. The gas sparger 106, 206 can be a static sparger. The gas sparger 106, 206 can be a single element sparger or a double element sparger.

[0030] The gas feed line 111, 211 can be coupled to a gas source 112, 212, *e.g.*, gas cylinders. The gas feeds can include, but are not limited to, reactants, reagents, catalysts, co-catalysts, initiators, oxidants, reductants, solvents, or a combination comprising at least one of the foregoing. For example, the gas feeds can include olefin compounds including, but not limited to, ethylene. The gas feeds can include hydrogen gas. Hydrogen gas can help to reduce polymer fouling.

[0031] The combination of agitator 103 and gas sparger 106, 206 can provide the benefits of both a continuously stirred tank reactor (CSTR) and a bubble column reactor (BCR) and improve mixing as compared to previously existing methods. The combination of agitator 103 and gas sparger 106, 206 can improve efficiency, selectivity, and other properties of reactions that are limited by diffusion. The combination of agitator 103 and gas sparger 106, 206 can reduce temperature gradients within the reaction vessel, which can improve the quality and purity of the reaction products.

[0032] The reactor 100, 200 can be heated or cooled via an external jacket 107, 207 mounted on or in proximity to the reactor. The jacket 107, 207 can have any desirable configuration to circulate a heating or cooling medium and can be made of any desirable material.

[0033] The jacket 107, 207 can control the temperature of the reaction performed in the reaction chamber by circulating a service fluid that functions as a heating medium and/or a cooling medium through a jacket inlet 108, 208 and a jacket outlet 109, 209. For example, service fluids can include DOWTHERM™, THERMINOL®, SYLTHERM™, other silicone

oils, water, organic oils, glycols (*e.g.*, ethylene glycol and propylene glycol), and similar fluids, as well as mixtures and combinations comprising at least one of the foregoing. In certain non-limiting embodiments, the temperature of a service fluid used as a cooling medium can be about -110 °C to about 20 °C.

[0034] Use of the jacket 107, 207 can help to control and regulate the temperature of the reactor 100, 200 and the reaction vessel 101, 201. Control and regulation of reactor and reaction vessel temperature can be important, *e.g.*, when a process is exothermic or endothermic.

[0035] The gas introduced via the gas sparger 106, 206 can also assist in removing heat from the reactor and cooling the reaction vessel. Thus the reactor can provide dual cooling modes, using both an external jacket 107, 207 and gas bubbling to provide improved heat removal from the system. Effective heat removal from the reactor can help to prevent thermal runaway. Accordingly, the reactor 100, 200 can include a cooling coil but does not require one.

[0036] The reactor 100, 200 can include a liquid distributor 114, 214 and a liquid feed line 110, 210. The liquid distributor 114, 214 can be located proximate the top of the reaction vessel 101, 201 and adapted to be connected to the liquid feed line 110, 210. For example, the liquid distributor 114, 214 can be located at the top or within about 20% to about 35% of the distance from the top of the reaction vessel 101, 201 to the bottom of the reaction vessel 101, 201. The liquid feed line 110, 210 and liquid distributor 114, 214 can provide liquids to the reaction vessel. The liquid feed can be a suitable diluted or concentrated fluid known to one of ordinary skill in the art. The liquid feeds can include, but are not limited to, reactants, reagents, catalysts, co-catalysts, initiators, oxidants, reductants, solvents, or a combination comprising at least one of the foregoing. Non-limiting examples of liquid feeds can include hydrocarbon solvents, *e.g.*, toluene, hexanes, cyclohexanes, or a combination comprising at least one of the foregoing. While a single liquid feed line 110, 210 is shown in Figures 1 and 2, multiple liquid feed lines can be used.

[0037] In certain embodiments of the disclosed subject matter, the liquid feed line 110, 210 can incorporate one or more drying filters. The drying filters can remove water.

[0038] The reactor 100, 200 can include plurality of thermocouples 113, 213 located at various locations on the reactor. The thermocouples can be configured for kinetic evaluation. For example, the thermocouples can be configured to assist in monitoring reactor system performance by detecting flow maldistribution, channeling, and other occurrences. The thermocouples can be multipoint thermocouples. The thermocouples can be connected

to the reactor by suitable methods known to one of ordinary skill in the art, for example by Pt 100 connections. The connections can be wire-wound, thin-film, and/or coil.

[0039] The reactor 100, 200 can include a catalyst preformation system 115, 215. The catalyst preformation system can be coupled to the liquid feed line 110, 210. Alternatively, the catalyst preformation system can be coupled to the reactor 100, 200 and the reaction vessel 101, 201 without coupling to the liquid feed line 110, 210. The catalyst preformation system 115, 215 can dose one catalyst solution. Alternatively, in certain embodiments of the disclosed subject matter, the catalyst preformation system 115, 215 can combine two or more catalyst or pre-catalyst solutions. In certain preferred embodiments, the catalyst preformation system 115, 215 can combine two or three catalyst or pre-catalyst solutions. The catalyst preformation system 115, 215 can combine two or more catalyst or pre-catalyst solutions to provide a combined catalyst solution. Upon introduction of catalyst to the reaction vessel 101, 201, various reactions can be catalyzed.

[0040] The reactor 100, 200 can include a demister 116, 216. In certain embodiments of the disclosed subject matter, the demister 116, 216 can be proximate the top of the reaction vessel 101, 201. For example, the demister 116, 216 can be located at the top or within about 10% to about 25% of the distance from the top of the reaction vessel to the bottom of the reaction vessel 101, 201. The demister 116, 216 can be a removable demister. In certain embodiments, the demister 116, 216 can be a wire mesh demister pad. The demister 116, 216 can allow vapors to pass through while collecting liquid droplets and causing liquids to drip down into the reaction vessel 101, 201. In certain embodiments, the demister 116, 216 can collect liquid droplets having a particle size of about 10 micrometers to about 100 micrometers. The demister 116, 216 can be used when the reactor 100, 200 does not include an agitator 103.

[0041] The reactor 100, 200 can include a product line 117, 217 coupled to the reactor. The product line 117, 217 is coupled to the reactor 100, 200 to remove products from the reaction vessel 101, 201. While a single product line 117 is shown in Figure 1, multiple product lines 217 can be used, as shown in Figure 2. The product line 117, 217 can be disposed along a side of the reaction vessel, at the bottom of the reaction vessel, and/or at other points on the reaction vessel. The product line 117, 217 can include one or more sample ports, as shown in Figure 2. In certain embodiments of the disclosed subject matter, the product line 117, 217 can be further coupled to a separation system 118, 218. The separation system 118, 218 can be used to purify reactor effluents and to separate reactor effluents into various valuable products. For example, the separation system 118, 218 may

be used to quench one or more catalysts according to techniques known to one of ordinary skill in the art.

[0042] The reactor 100, 200 can include a sight glass 119, 219. The sight glass 119, 219 can be oriented at a 180 degree angle to the vertical axis of the reactor 100, 200. The sight glass 119, 219 can be used for various purposes, including, but not limited to, monitoring of conditions inside the reaction vessel 101, 201. The sight glass 119, 219 can be configured for monitoring a reaction performed in the reactor, monitoring a dosing fed to the reactor, monitoring a mixing pattern in the reactor, and/or monitoring a product property in the reactor.

[0043] In certain embodiments of the disclosed subject matter, the reactor 100, 200 can be operated in a continuous mode or a semi-continuous mode. The reactor 100, 200 can also be operated in a batch mode, *e.g.*, by isolating the product line(s) 117, 217. The disclosed reactor 100, 200 can be operated at variable pressures and temperatures. In certain non-limiting embodiments, the pressure within the reactor 100, 200 and within the reaction vessel 101, 201 can be about 1 MegaPascal (MPa) to about 12 MPa (about 10 bar to about 120 bar). In certain preferred embodiments, the pressure can be about 2 MPa to about 7 MPa (about 20 bar to about 70 bar). In certain non-limiting embodiments, the temperature within the reactor 100, 200 and within the reaction vessel 101, 201 can be about 30 °C to about 70 °C. The operation temperature and pressure can depend on the process requirements for the desired reaction.

[0044] The reactor 100, 200 can be configured to perform one or more catalytic reactions, such as oxidation, hydrogenation, condensation, alkylation, etc. The reactor can be used for performing homogenous catalytic endothermic or exothermic processes for making any desirable chemicals, polymers, petrochemicals, agricultural chemicals, and/or pharmaceuticals. In certain embodiments of the disclosed subject matter, oligomerization reactions can be performed. For example, an olefinic feed such as ethylene can be the substrate for oligomerization. Ethylene can be oligomerized to produce higher olefins such as 1-butene, 1-hexene, 1-octene, 1-decene, 1-dodecene, and higher olefins.

[0045] The reactor 100, 200 can further include any accessories known to one of ordinary skill in the art, including, but not limited to, measurement accessories, heating elements, pH monitors, density meters, and viscometers. The reactor 100, 200 can also include any suitable safety device including, but not limited to, rupture discs, pressure safety valves (PSV), and/or gas detectors (*e.g.*, detectors for carbon monoxide, oxygen, hydrogen, and ammonia). Exemplary measurement accessories can be any measurement accessories

known to one of ordinary skill in the art. For example, measurement accessories can include, but are not limited to, pressure indicators, pressure transmitters, thermowells, temperature-indicating controllers, and analyzers. These accessories can be placed at various locations on the reactor, for example, on the walls or at or proximate the top of the reactor. The reactor 100, 200 can include various safety equipment and measures known to one of ordinary skill in the art to reduce temperatures and/or pressures that are too high. These safety measures can thereby preclude and/or control thermal runaway.

[0046] The presently disclosed subject matter can also provide methods of performing processes, including, but not limited to, homogenous catalytic gas/liquid chemical reactions. In one embodiment, an exemplary method of performing a process can include providing a reactor 100, 200 including a reaction vessel 101, 201. A gas can then be introduced to the reaction vessel 101, 201 through a gas sparger 106, 206 coupled to a gas feed line 111, 211, which can be further coupled to a gas source 112, 212. A liquid can be introduced to the reaction vessel 101, 201 through a liquid distributor 114, 214 coupled to a liquid feed line 110, 210. A reaction can be performed in the reaction vessel 101, 201. Products of the reaction can be removed from the reaction vessel 101, 201 through one or more product lines 117, 217 coupled to the reaction vessel.

[0047] In certain embodiments of the disclosed subject matter, the process can be a homogenous catalytic process. In certain embodiments of the disclosed subject matter, one or more catalyst solutions to induce a gas/liquid chemical reaction can be introduced to the reaction vessel 101, 201 from a catalyst preformation system 115, 215, which can be coupled to the liquid feed line 110, 210 or, alternatively, coupled directly to the reaction vessel 101, 201.

[0048] In certain embodiments of the disclosed subject matter, the reaction can include one or more oligomerization reactions. The oligomerization reactions can include an oligomerization of ethylene to one or more of 1-butene, 1-hexene, 1-octene, or a combination including at least one of the foregoing. Methods of performing homogenous catalytic processes can include feeding ethylene gas into the reaction vessel 101, 201 through a gas sparger 106, 206, allowing ethylene to oligomerize under homogenous catalytic conditions, and removing one or more of 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing as product(s) of the reaction through a product line 117, 217 coupled to the reaction vessel. The selectivity of oligomerization of ethylene can depend on the nature of the catalyst system used. Different catalyst systems can favor oligomerization of ethylene to produce 1-butene, 1-hexene, 1-octene, 1-decene, 1-dodecene, and/or higher

olefins. For example, catalyst systems can be sensitive to trace impurities in the feed and/or reaction liquids. Such impurities can alter the nature of catalyst systems and can, under some circumstances, favor formation of undesired side products over desired products.

[0049] The reactors and methods disclosed herein include at least the following embodiments:

[0050] Embodiment 1: A reactor for performing processes for a product line, comprising: a reaction vessel adapted to be coupled to the product line; a gas sparger adapted to be coupled to a gas feed line; and a liquid distributor proximate a top of the reaction vessel and adapted to be coupled to a liquid feed line.

[0051] Embodiment 2: The reactor of Claim 1, wherein the gas sparger is configured to permit introduction of a gas through a plurality of locations along at least one side of the reactor.

[0052] Embodiment 3: The reactor of Claim 1 or Claim 2, wherein the gas sparger is proximate a bottom of the reaction vessel.

[0053] Embodiment 4: The reactor of any of Claims 1-3, wherein the reactor further comprises an agitator.

[0054] Embodiment 5: The reactor of Claim 4, wherein the agitator is proximate the bottom of the reaction vessel.

[0055] Embodiment 6: The reactor of any of Claims 1-5, further comprising a catalyst preformation system coupled to the liquid feed line.

[0056] Embodiment 7: The reactor of Claim 6, wherein the catalyst preformation system is configured to dose one or more catalyst solutions.

[0057] Embodiment 8: The reactor of any of Claims 1-7, further comprising a demister proximate the top of the reaction vessel.

[0058] Embodiment 9: The reactor of Claim 8, wherein the demister comprises a removable demister.

[0059] Embodiment 10: The reactor of any of Claims 1-9, further comprising a jacket coupled to the reactor and configured to circulate a heating or cooling medium therearound.

[0060] Embodiment 11: The reactor of Claim 10, wherein the jacket is configured to provide heat or to remove heat from the reaction vessel.

[0061] Embodiment 12: The reactor of any of Claims 1-11, wherein the product line is coupled to a separation system.

[0062] Embodiment 13: The reactor of any of Claims 1-12, further comprising thermocouples at a plurality of locations on the reactor.

[0063] Embodiment 14: The reactor of any of Claims 1-13, wherein the reaction vessel comprises a sight glass.

[0064] Embodiment 15: The reactor of Claim 14, wherein the sight glass is configured for monitoring one or more of a reaction performed in the reactor, a dosing fed to the reactor, a mixing pattern in the reactor, and a product property in the reactor.

[0065] Embodiment 16: The reactor of any of Claims 1-15, wherein the reactor is configured to perform oligomerization reactions.

[0066] Embodiment 17: A method of performing a process, comprising: providing a reactor comprising a reaction vessel; introducing a gas to the reaction vessel through a gas sparger coupled to the reaction vessel and a gas feed line; introducing a liquid to the reaction vessel through a liquid distributor proximate a top of the reaction vessel and coupled to a liquid feed line; performing a reaction in the reaction vessel; and removing a product from the reaction vessel through a product line coupled to the reaction vessel.

[0067] Embodiment 18: The method of Claim 17, wherein the process is a homogenous catalytic process.

[0068] Embodiment 19: The method of Claim 17 or Claim 18, wherein the reaction comprises an oligomerization reaction.

[0069] Embodiment 20: The method of any of Claims 17-19, wherein the product comprises one or more of 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing.

[0070] 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.

[0071] Although the presently disclosed subject matter and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the disclosed subject matter as defined by the appended claims. Moreover, the scope of the disclosed subject matter is not intended to be limited to the particular embodiments described in the specification. As one of ordinary skill in the art will readily appreciate from the disclosure of the disclosed subject matter, alternatives presently existing or later to be developed that perform substantially the same function or achieve substantially the same result as the corresponding embodiments described herein can be utilized according to the presently

disclosed subject matter. Accordingly, the appended claims are intended to include within their scope such alternatives.

[0072] A more complete understanding of the components, processes, and apparatuses disclosed herein can be obtained by reference to the accompanying drawings. These figures (also referred to herein as “FIG.”) are merely schematic representations based on convenience and the ease of demonstrating the present disclosure, and are, therefore, not intended to indicate relative size and dimensions of the devices or components thereof and/or to define or limit the scope of the exemplary embodiments. Although specific terms are used in the following description for the sake of clarity, these terms are intended to refer only to the particular structure of the embodiments selected for illustration in the drawings, and are not intended to define or limit the scope of the disclosure. In the drawings and the following description below, it is to be understood that like numeric designations refer to components of like function.

[0073] In general, the invention may alternately comprise, consist of, or consist essentially of, any appropriate components herein disclosed. The invention may additionally, or alternatively, be formulated so as to be devoid, or substantially free, of any components, materials, ingredients, adjuvants or species used in the prior art compositions or that are otherwise not necessary to the achievement of the function and/or objectives of the present invention. The endpoints of all ranges directed to the same component or property are inclusive and independently combinable (e.g., ranges of “less than or equal to 25 wt%, or 5 wt% to 20 wt%,” is inclusive of the endpoints and all intermediate values of the ranges of “5 wt% to 25 wt%,” etc.). Disclosure of a narrower range or more specific group in addition to a broader range is not a disclaimer of the broader range or larger group. “Combination” is inclusive of blends, mixtures, alloys, reaction products, and the like. Furthermore, the terms “first,” “second,” and the like, herein do not denote any order, quantity, or importance, but rather are used to denote one element from another. The terms “a” and “an” and “the” herein do not denote a limitation of quantity, and are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. “Or” means “and/or.” The suffix “(s)” as used herein is intended to include both the singular and the plural of the term that it modifies, thereby including one or more of that term (e.g., the film(s) includes one or more films). Reference throughout the specification to “one embodiment”, “another embodiment”, “an embodiment”, and so forth, means that a particular element (e.g., feature, structure, and/or characteristic) described in connection with the embodiment is included in at least one embodiment described herein, and may or may not be present in other

embodiments. In addition, it is to be understood that the described elements may be combined in any suitable manner in the various embodiments.

[0074] The modifier “about” used in connection with a quantity is inclusive of the stated value and has the meaning dictated by the context (e.g., includes the degree of error associated with measurement of the particular quantity). The notation “ $\pm 10\%$ ” means that the indicated measurement can be from an amount that is minus 10% to an amount that is plus 10% of the stated value. The terms “front”, “back”, “bottom”, and/or “top” are used herein, unless otherwise noted, merely for convenience of description, and are not limited to any one position or spatial orientation. “Optional” or “optionally” means that the subsequently described event or circumstance can or cannot occur, and that the description includes instances where the event occurs and instances where it does not. Unless defined otherwise, technical and scientific terms used herein have the same meaning as is commonly understood by one of skill in the art to which this invention belongs. A “combination” is inclusive of blends, mixtures, alloys, reaction products, and the like.

[0075] All cited patents, patent applications, and other references are incorporated herein by reference in their entirety. However, if a term in the present application contradicts or conflicts with a term in the incorporated reference, the term from the present application takes precedence over the conflicting term from the incorporated reference.

[0076] While particular embodiments have been described, alternatives, modifications, variations, improvements, and substantial equivalents that are or may be presently unforeseen may arise to applicants or others skilled in the art. Accordingly, the appended claims as filed and as they may be amended are intended to embrace all such alternatives, modifications variations, improvements, and substantial equivalents.

CLAIMS:

1. A reactor for performing processes for a product line, comprising:
a reaction vessel adapted to be coupled to the product line;
a gas sparger adapted to be coupled to a gas feed line; and
a liquid distributor proximate a top of the reaction vessel and adapted to be coupled to a liquid feed line.
2. The reactor of Claim 1, wherein the gas sparger is configured to permit introduction of a gas through a plurality of locations along at least one side of the reactor.
3. The reactor of Claim 1 or Claim 2, wherein the gas sparger is proximate a bottom of the reaction vessel.
4. The reactor of any of Claims 1-3, wherein the reactor further comprises an agitator.
5. The reactor of Claim 4, wherein the agitator is proximate the bottom of the reaction vessel.
6. The reactor of any of Claims 1-5, further comprising a catalyst preformation system coupled to the liquid feed line.
7. The reactor of Claim 6, wherein the catalyst preformation system is configured to dose one or more catalyst solutions.
8. The reactor of any of Claims 1-7, further comprising a demister proximate the top of the reaction vessel.
9. The reactor of Claim 8, wherein the demister comprises a removable demister.
10. The reactor of any of Claims 1-9, further comprising a jacket coupled to the reactor and configured to circulate a heating or cooling medium therearound.

11. The reactor of Claim 10, wherein the jacket is configured to provide heat or to remove heat from the reaction vessel.
12. The reactor of any of Claims 1-11, wherein the product line is coupled to a separation system.
13. The reactor of any of Claims 1-12, further comprising thermocouples at a plurality of locations on the reactor.
14. The reactor of any of Claims 1-13, wherein the reaction vessel comprises a sight glass.
15. The reactor of Claim 14, wherein the sight glass is configured for monitoring one or more of a reaction performed in the reactor, a dosing fed to the reactor, a mixing pattern in the reactor, and a product property in the reactor.
16. The reactor of any of Claims 1-15, wherein the reactor is configured to perform oligomerization reactions.
17. A method of performing a process, comprising:
 - providing a reactor comprising a reaction vessel;
 - introducing a gas to the reaction vessel through a gas sparger coupled to the reaction vessel and a gas feed line;
 - introducing a liquid to the reaction vessel through a liquid distributor proximate a top of the reaction vessel and coupled to a liquid feed line;
 - performing a reaction in the reaction vessel; and
 - removing a product from the reaction vessel through a product line coupled to the reaction vessel.
18. The method of Claim 17, wherein the process is a homogenous catalytic process.
19. The method of Claim 17 or Claim 18, wherein the reaction comprises an oligomerization reaction.

20. The method of any of Claims 17-19, wherein the product comprises one or more of 1-butene, 1-hexene, 1-octene, or a combination comprising at least one of the foregoing.