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(54) **SYSTEM AND METHOD FOR GENERATING SYNTHETIC FUEL**

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(57)

ABSTRACT

(22) Filed: **Feb. 14, 2025**

Related U.S. Application Data

(60) Provisional application No. 63/554,759, filed on Feb. 16, 2024.

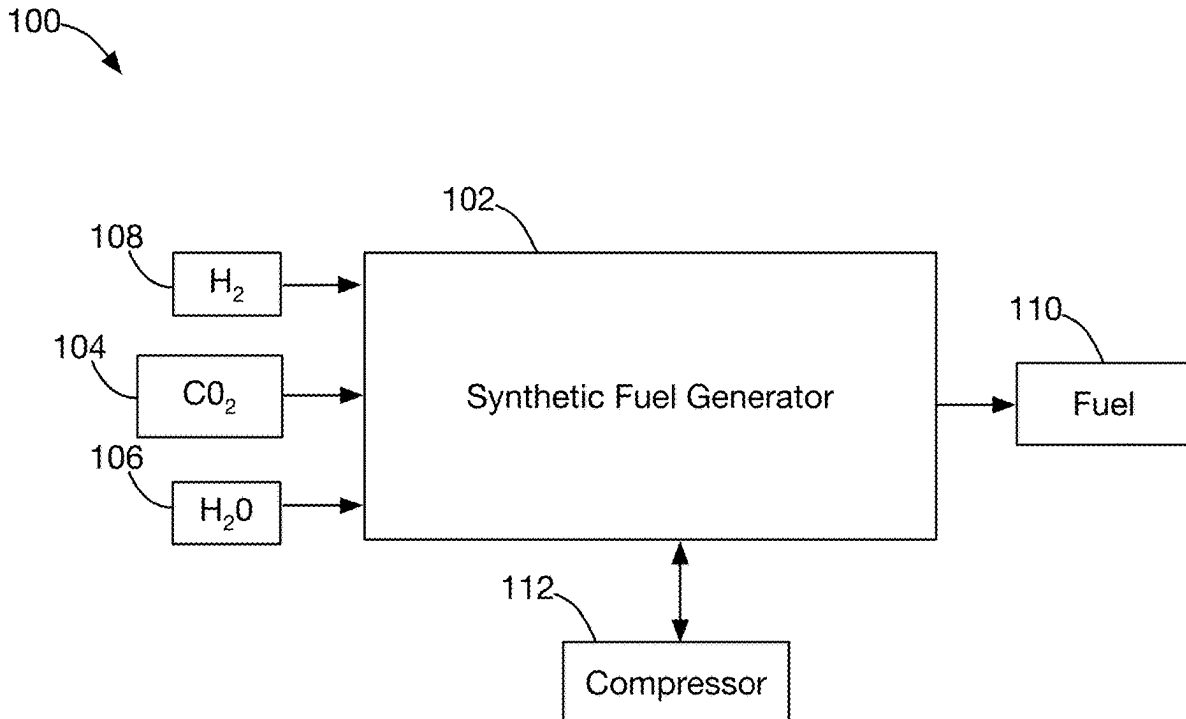
A fuel generator and a method for generating fuel are disclosed in which a monolithic block includes a plurality of plates stacked and bonded together. A first input port and a second input port are disposed on the monolithic block. The first input port is coupled to a source of hydrogen gas and the second input port is coupled to a source of carbon dioxide or syngas. An output port is disposed on the monolithic block and is coupled to a fuel reservoir. The plurality of plates form a plurality of reaction regions. At least a portion of the plurality of reaction regions convert one of the carbon dioxide or syngas and hydrogen into a hydrocarbon fuel that is supplied from the output port.

Publication Classification

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B01J 19/24 (2006.01)



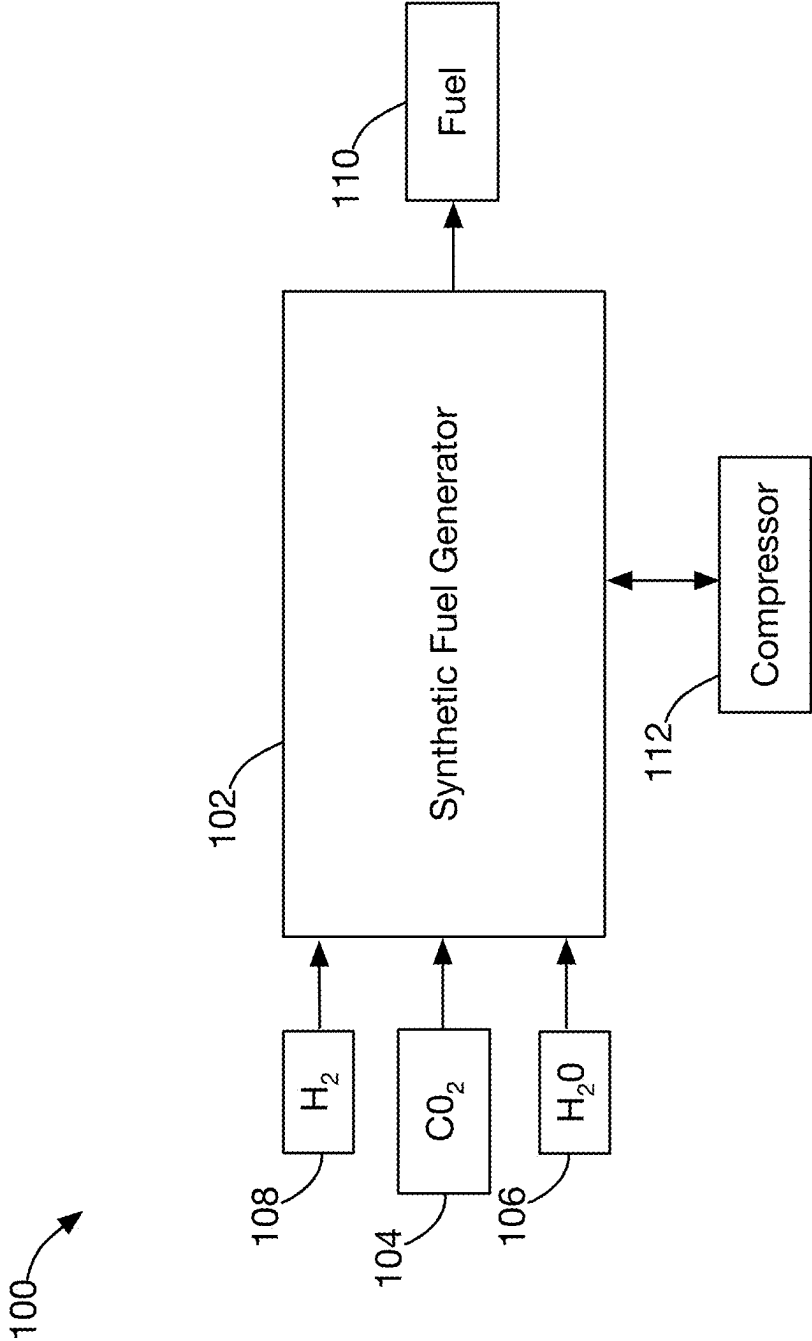


FIG. 1

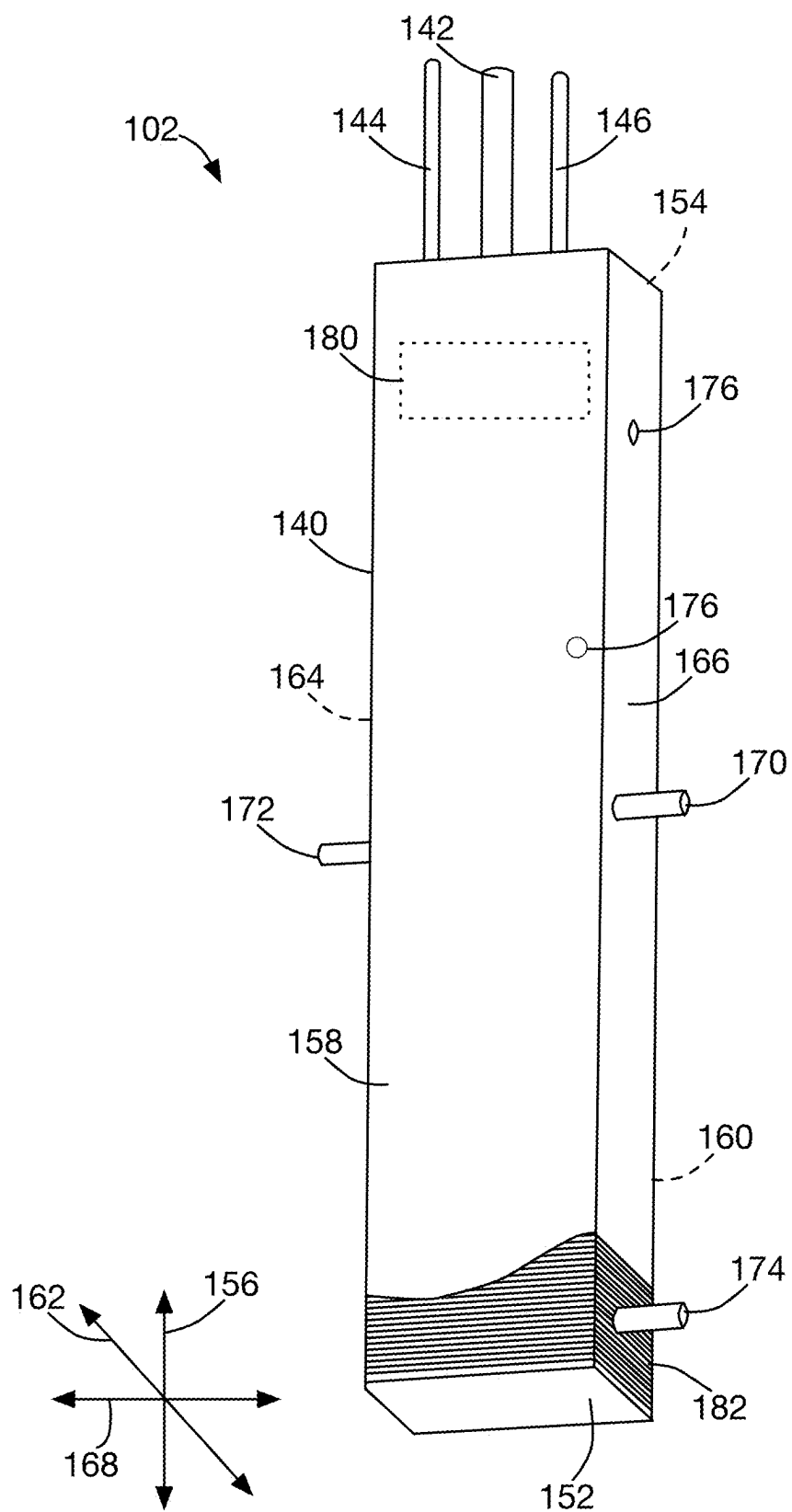


FIG. 2

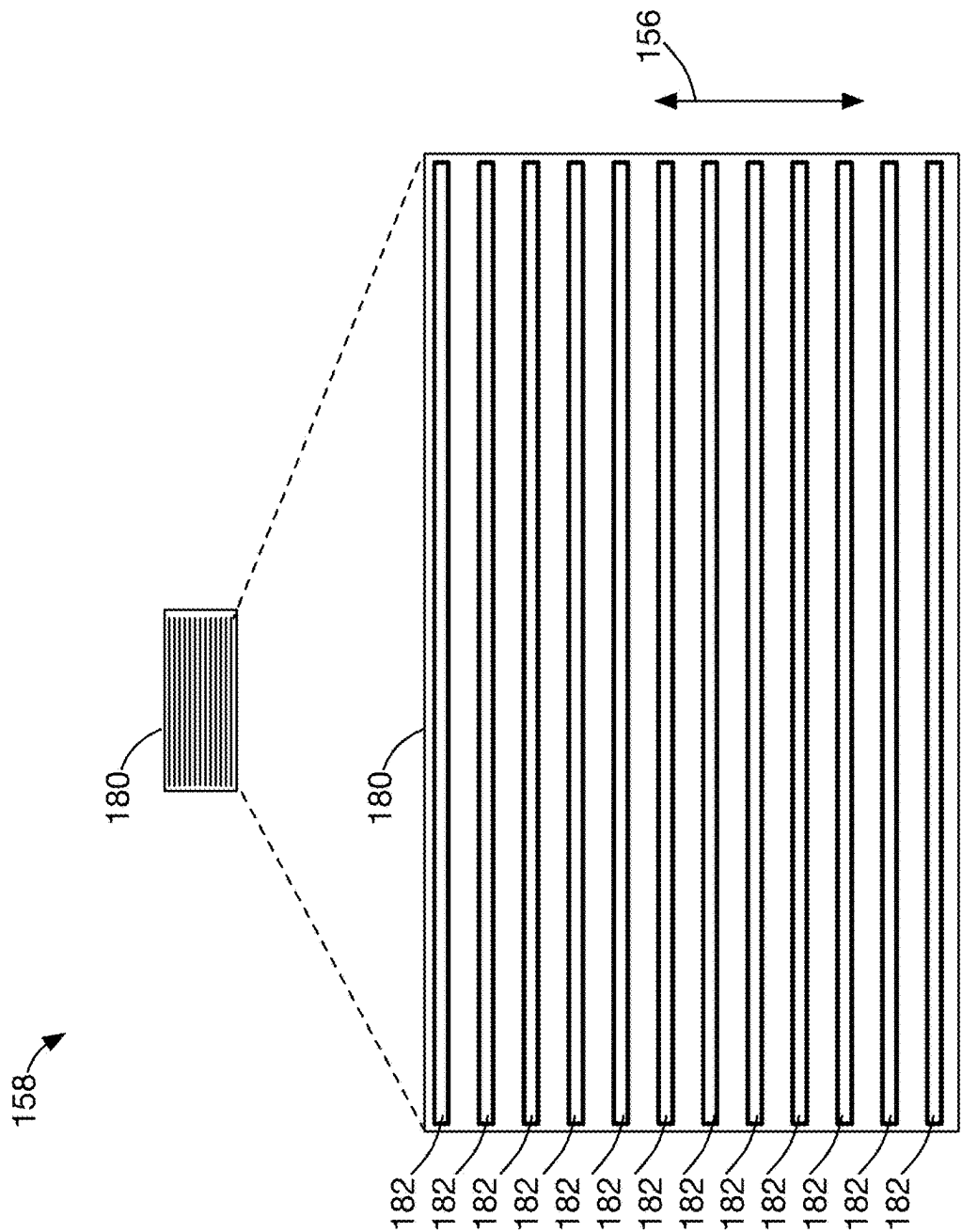


FIG. 3

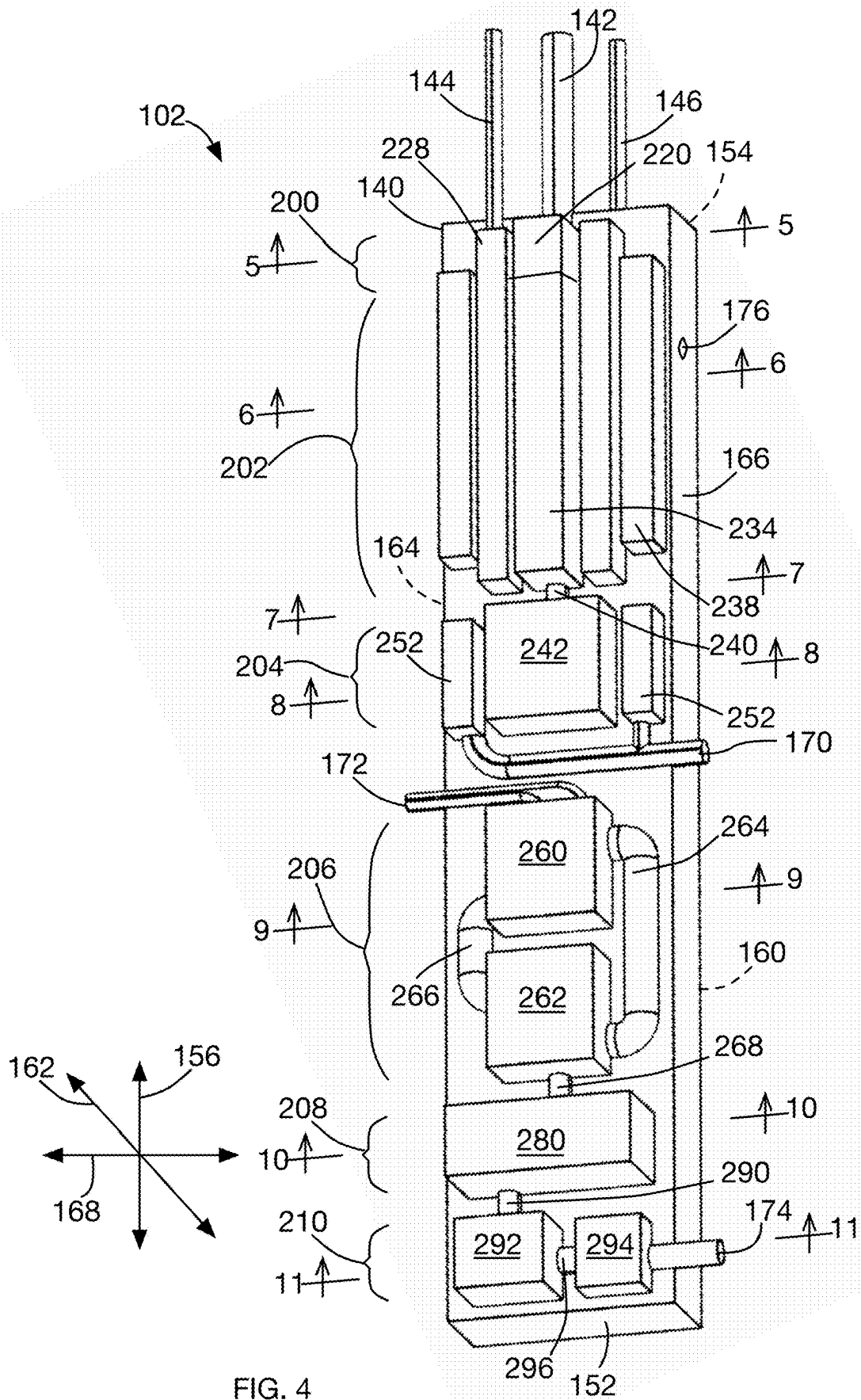


FIG. 4

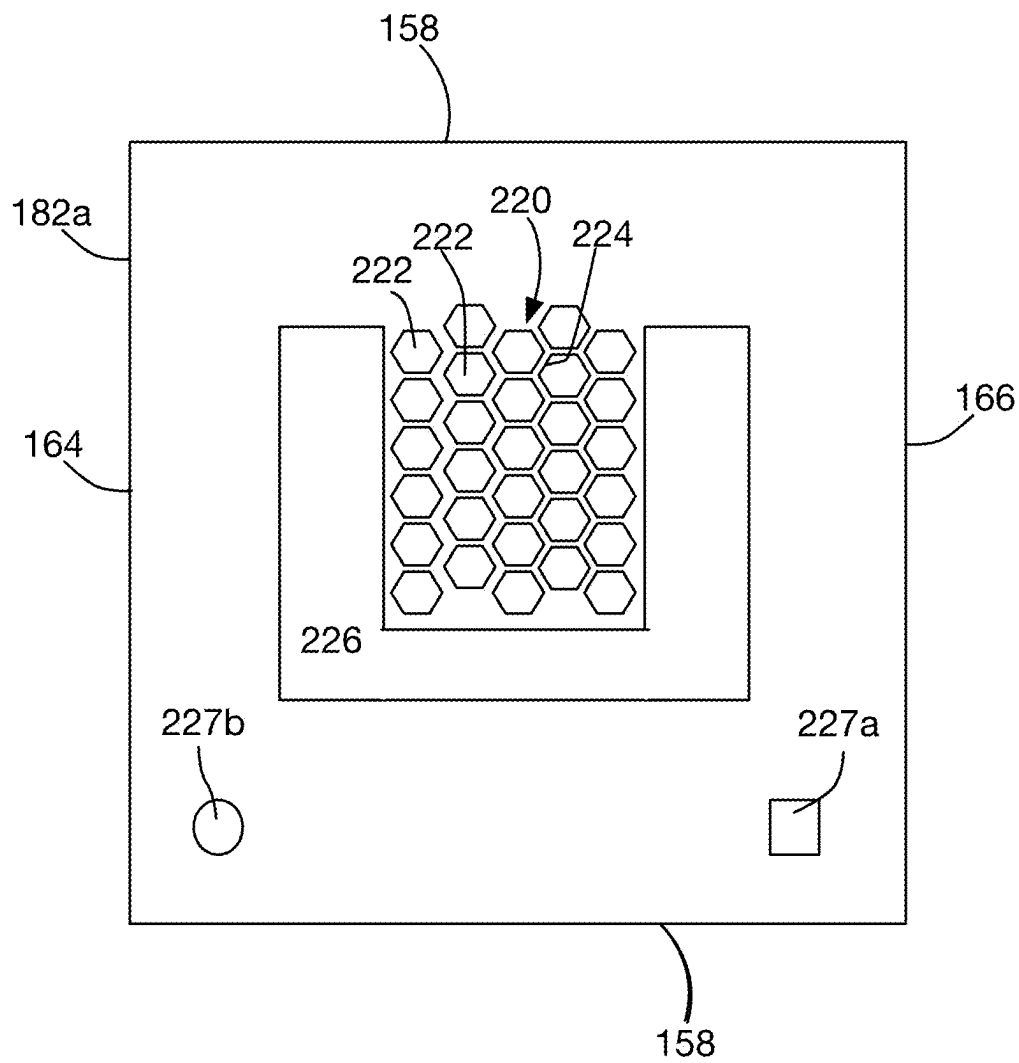


FIG. 5

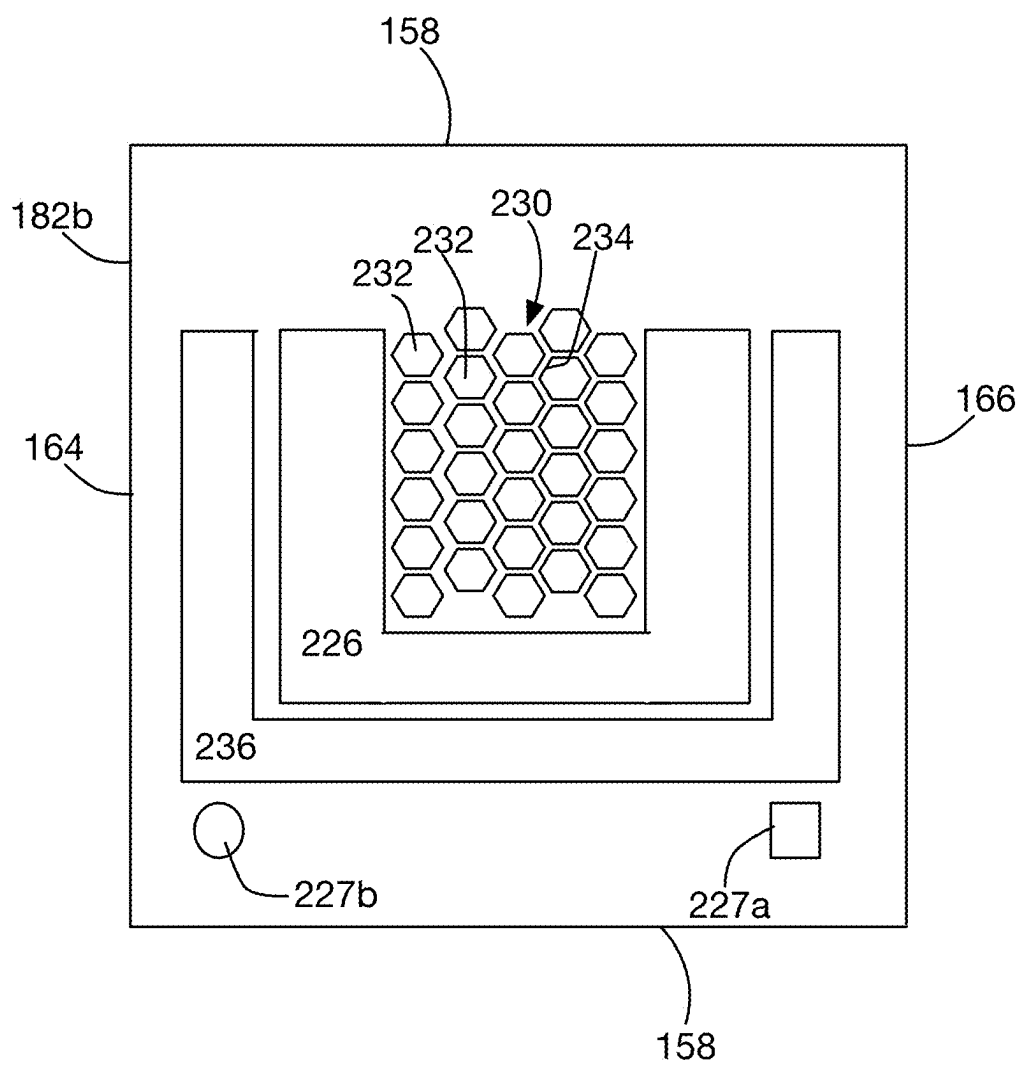


FIG. 6

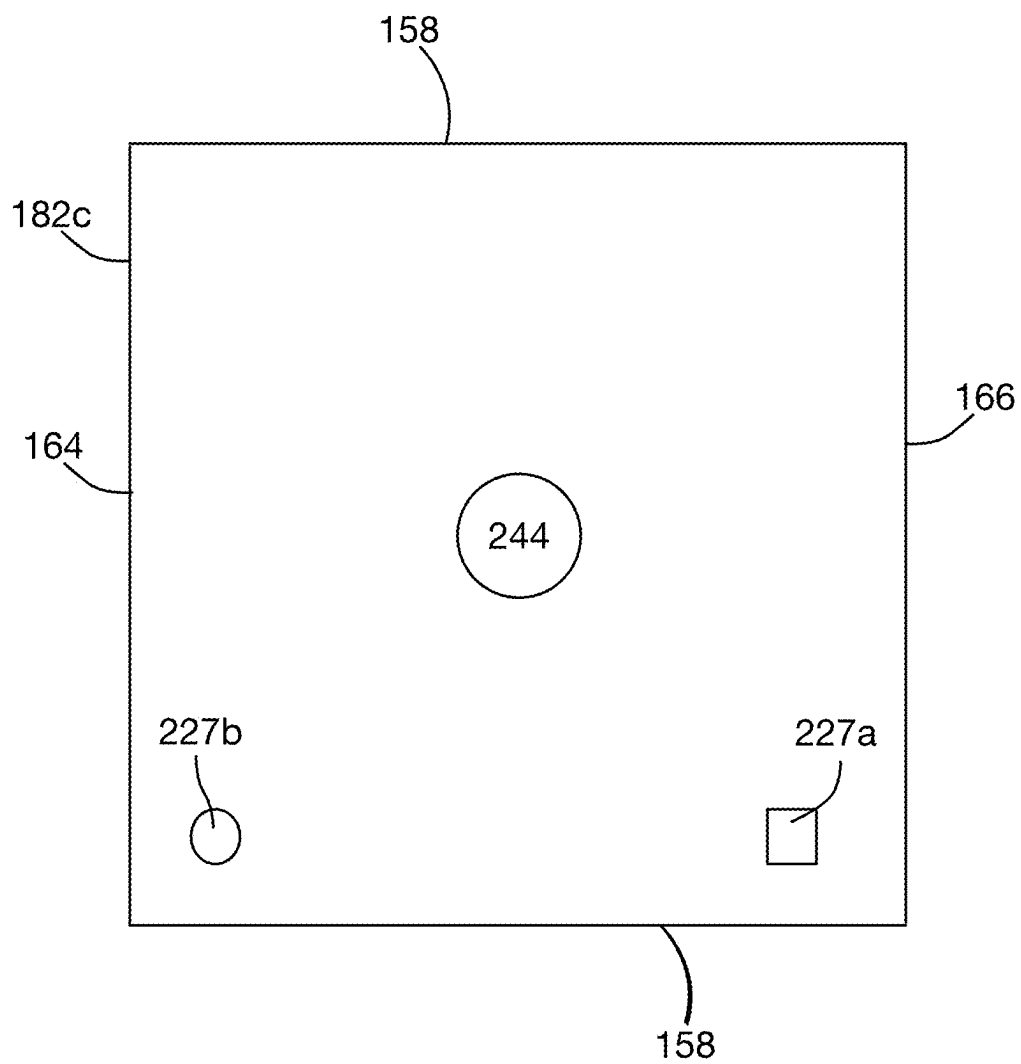


FIG. 7

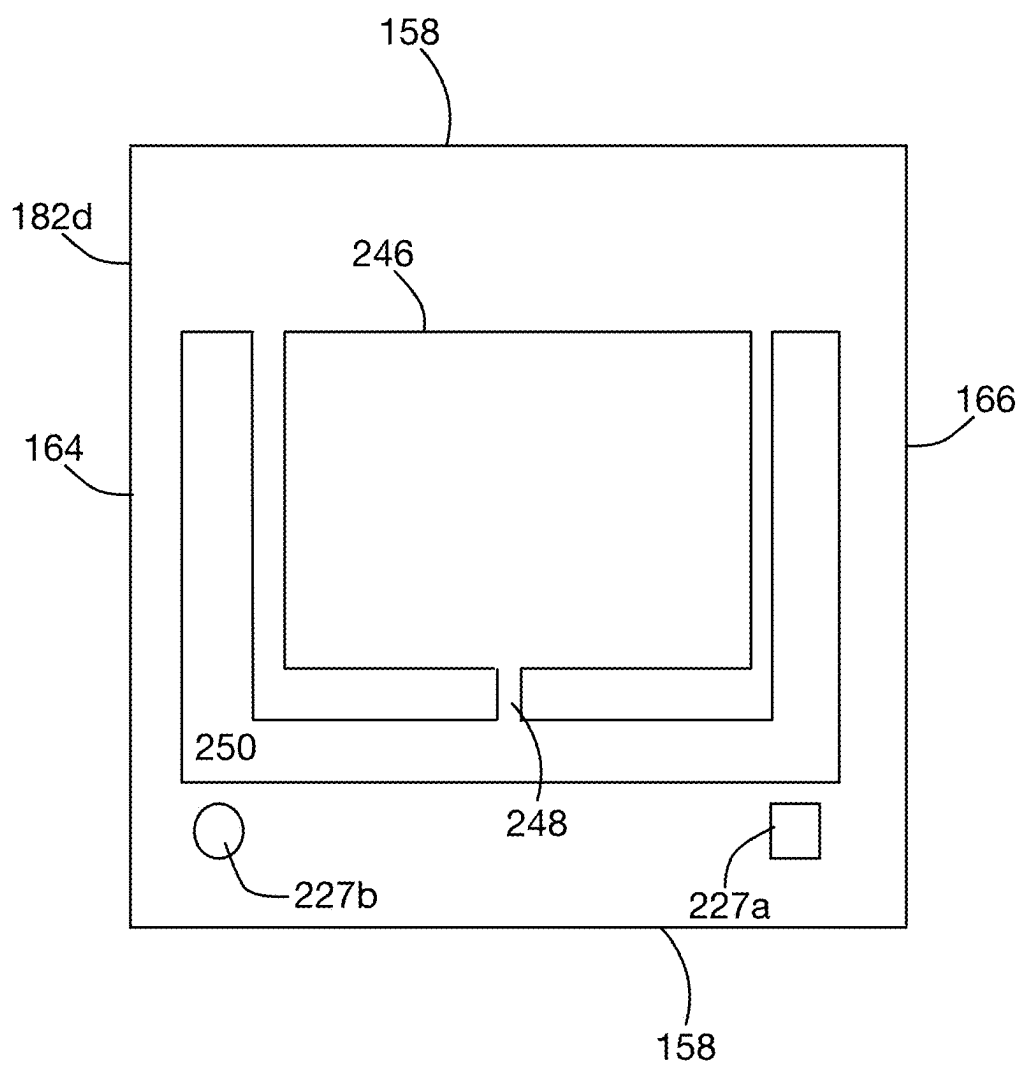


FIG. 8

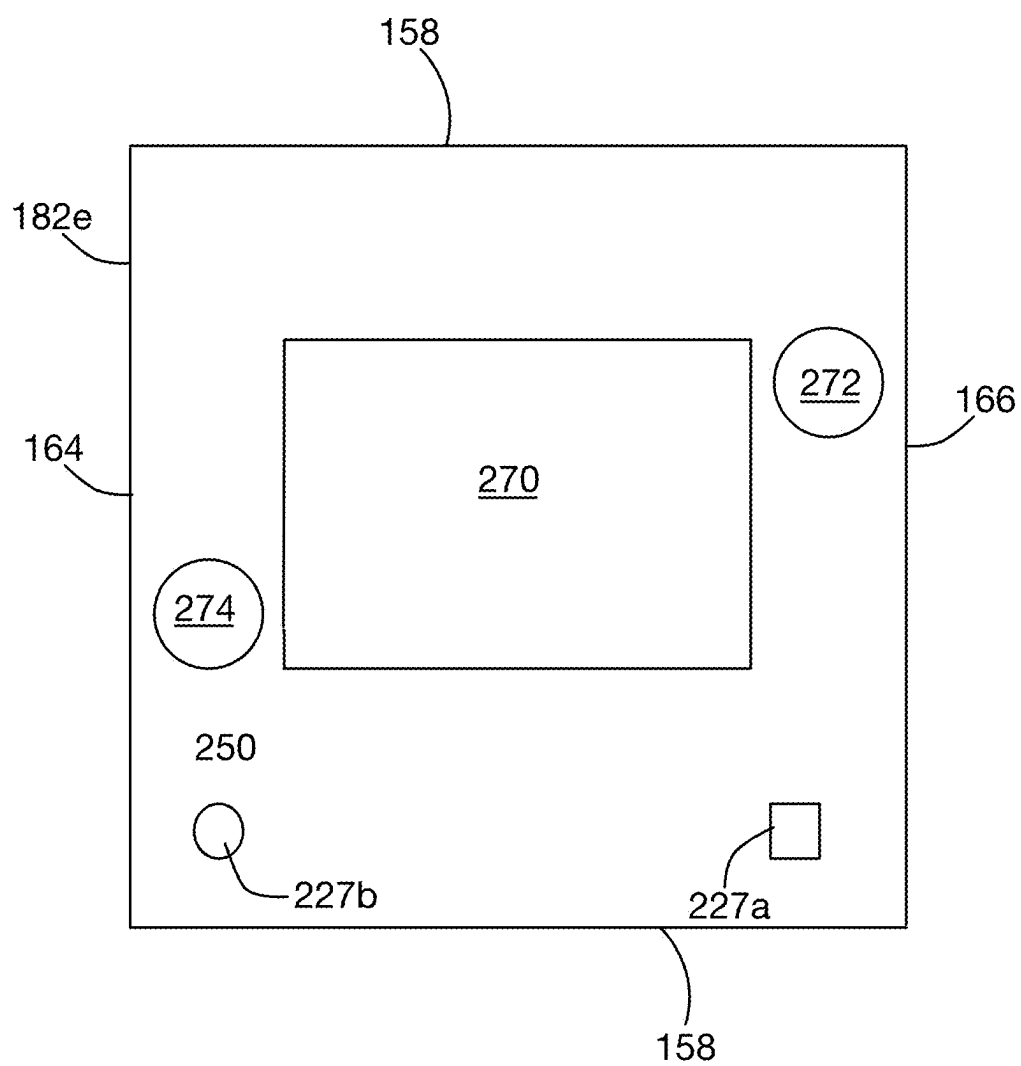


FIG. 9

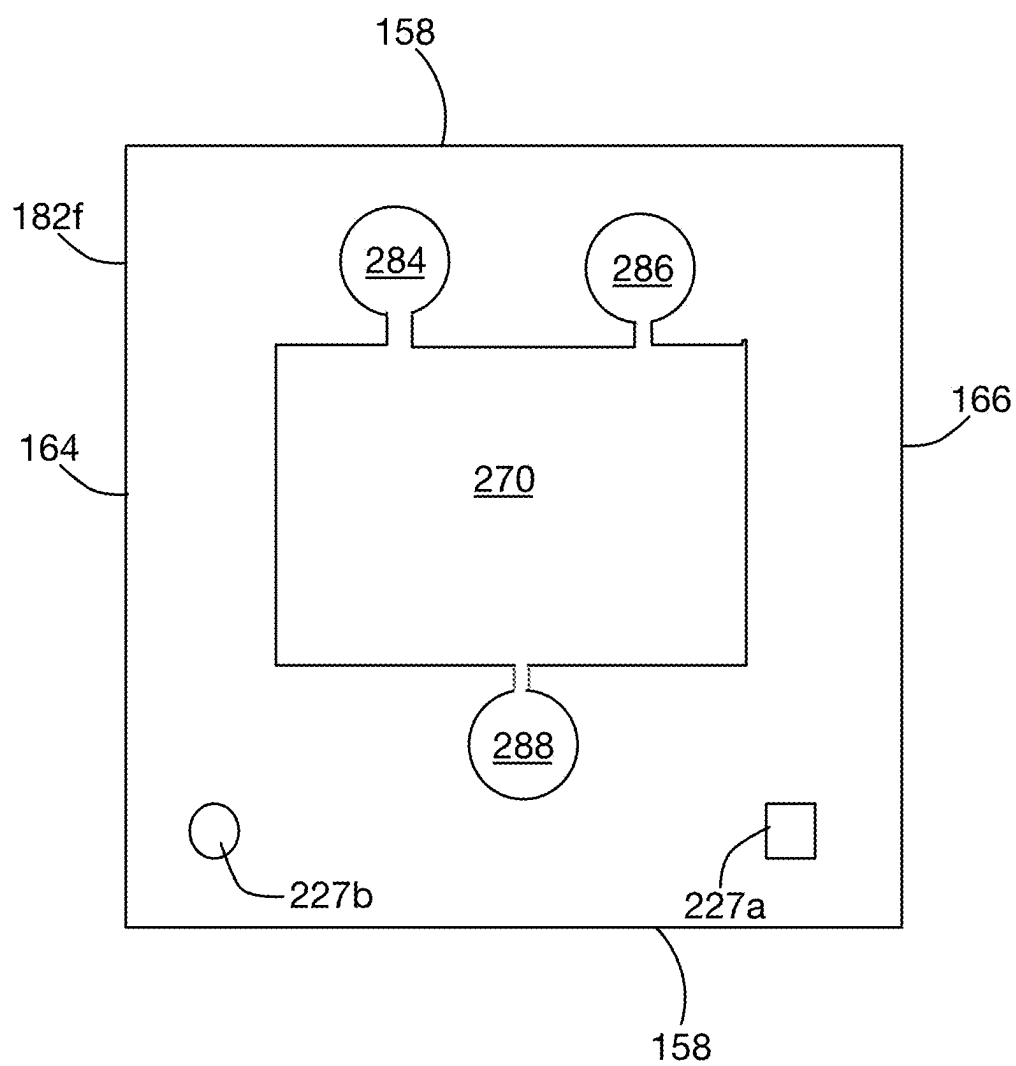


FIG. 10

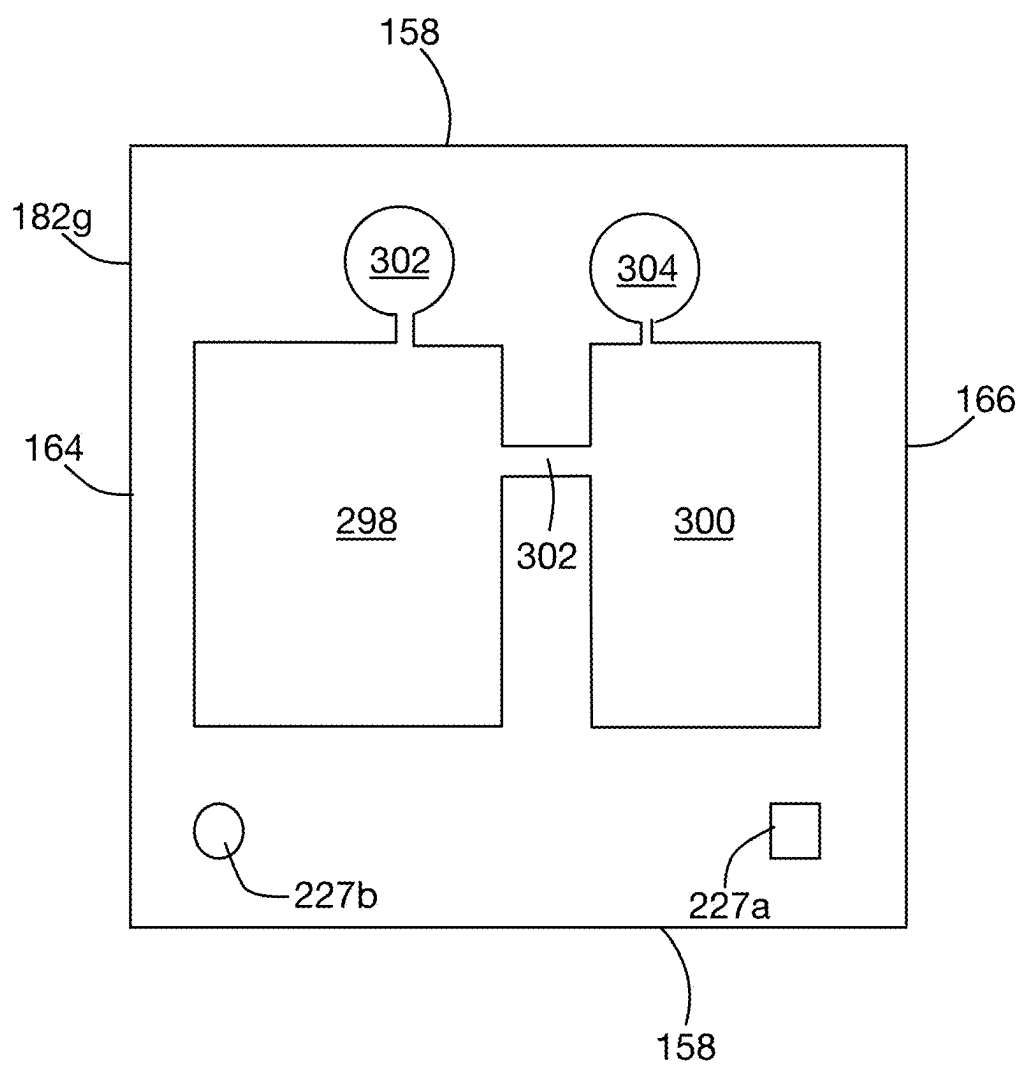


FIG. 11

SYSTEM AND METHOD FOR GENERATING SYNTHETIC FUEL

CROSS-REFERENCE TO RELATED APPLICATION

[0001] The present application claims priority to Kutsch, U.S. Provisional Patent Application Ser. No. 63/554,759, filed Feb. 16, 2024, and entitled “Progressive Cascade Compact Oligomerizer for Efficient Evolution of Liquid Hydrocarbon Fuels,” the entire contents of which are incorporated herein by reference.

FIELD OF DISCLOSURE

[0002] The present subject matter relates to systems and methods for generating synthetic fuel and more particularly, a system and method for generating synthetic fuel from syngas.

BACKGROUND

[0003] Synthetic hydrocarbon fuels are a viable and sustainable substitute for conventional fuels extracted from petroleum sources, particularly in transportation applications that may consume substantial quantities of fuel. Such fuels have more energy density compared to other sources of energy such as hydrogen, batteries, non-hydrocarbon fuel, and the like and are particularly suited for use in, for example, aviation and maritime applications. The Fischer-Tropsch synthetic fuel production process uses catalyzed chemical reactions undertaken at high temperatures (between 150° and 300° Celsius) to convert syngas, a mixture of carbon monoxide and hydrogen gases in the presence of catalysts, into liquid hydrocarbons. The liquid hydrocarbons that result from these chemical reactions may include products such as diesel fuel, jet fuel, lubricants, blend stocks for gasoline fuels, and the like. The methanol to oligomerizer process generates hydrocarbon chains that are lengthened through a series of condensation polymerization reactions that result in alkane and alkene products.

[0004] A conventional production plant for production of synthetic fuels using the Fischer-Tropsch and related processes may include a number of discrete processing and storage tanks for producing and storing intermediate products, pipelines that connect such discrete tanks, and heating and cooling systems connected to such tanks and pipelines to maintain the temperature of the contents thereof to sustain the chemical reactions associated with this process.

SUMMARY

[0005] According to one aspect, a fuel generator includes a monolithic block comprising a plurality of plates stacked and bonded together. A first input port is disposed on the monolithic block and is coupled to a source of hydrogen gas, a second input port is disposed on the monolithic block and is coupled to a source of carbon dioxide or syngas, and an output port is disposed on the monolithic block and is coupled to a fuel reservoir. The plurality of plates form a plurality of reaction regions, wherein at least a portion of the plurality of reaction regions convert one of the carbon dioxide or syngas and hydrogen into a hydrocarbon fuel that is supplied from the output port.

[0006] A method for generating fuel includes providing a monolithic block. The monolithic block is formed from a plurality of plates stacked and bonded together to form a

plurality of reaction regions. The monolithic block includes a first input port, a second input port, and an output port. The method further includes supplying hydrogen gas to the first input port, supplying one of carbon dioxide or syngas to the second input port, converting the hydrogen gas and one of the carbon dioxide or syngas in the plurality of reaction region into a hydrocarbon fuel, and supplying the hydrocarbon fuel from the output port.

[0007] Other aspects and advantages will become apparent upon consideration of the following detailed description and the attached drawings wherein like numerals designate like structures throughout the specification.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a schematic diagram of a fuel generation system in accordance with the present disclosure;

[0009] FIG. 2 is an isometric view of a monolithic fuel generation block of the system of FIG. 1;

[0010] FIG. 3 is an exploded view of a portion of the monolithic fuel generation block of FIG. 1;

[0011] FIG. 4 is an isometric diagram of the monolithic fuel generation block of FIG. 1 with portion omitted to show internal sections of the monolithic fuel generation block.

[0012] FIG. 5 is a plan view of a plate that may form at least a portion of a syngas generation region of the monolithic fuel generation block of FIG. 1;

[0013] FIG. 6 is a plan view of a plate that may form at least a portion of a methanol generation region of the monolithic fuel generation block of FIG. 1;

[0014] FIG. 7 is a plan view of a plate that may form at least a portion of a conduit of the monolithic fuel generation block of FIG. 1;

[0015] FIG. 8 is a plan view of a plate that may form at least a portion of an olefin generation region of the monolithic fuel generation block of FIG. 1;

[0016] FIG. 9 is a plan view of a plate that may form at least a portion of an olefin oligomerization region of the monolithic fuel generation block of FIG. 1;

[0017] FIG. 10 is a plan view of a plate that may form at least a portion of a hydrogenation region of the monolithic fuel generation block of FIG. 1; and

[0018] FIG. 11 is a plan view of a plate that may form at least a portion of a fuel separation region of the monolithic fuel generation block of FIG. 1.

DETAILED DESCRIPTION

[0019] Referring to FIG. 1, a synthetic fuel generation system 100 to produce hydrocarbon fuel includes a monolithic fuel generator 102. Carbon dioxide from a carbon dioxide source 104, water from a water source 106, and hydrogen gas from a hydrogen gas source 108 are provided to fuel generator 102. The fuel generation system 100 processes the carbon dioxide, water, and hydrogen supplied thereto as described below to produce hydrocarbon based fuel that is supplied to and stored in a fuel reservoir or holding tank 110. In some embodiments, syngas (a mixture of hydrogen and carbon monoxide) may be provided to the fuel generator 102 instead of carbon dioxide and the fuel generation system 100 processes the syngas, water, and hydrogen supplied thereto to produce the hydrocarbon based fuel. In addition, the synthetic fuel generation system 100 includes a compressor 112 fluidically coupled to the fuel generator and intermediate products generated by the fuel

generation system **100** are supplied to the compressor **112** at a first pressure, compressed (i.e., pressurized), and returned from the compressor **112** to the fuel generation system **100** at a second pressure greater than the first pressure.

[0020] As discussed in greater detail below, the fuel generator **102** includes a plurality of reaction regions in which catalytic reactions and other processes occur to convert the carbon dioxide and water (or hydrogen gas) into syngas, the syngas into methanol, and the methanol into olefins. Hydrogen from the hydrogen source **108** is thereafter used to hydrogenate the olefins to produce the fuel, e.g., a synthetic aircraft fuel and supplied to the fuel reservoir **110**. The fuel generator **102** may be adapted to generate fuel including, for example, long chain hydrocarbons, saturated linear hydrocarbons, paraffins, gasoline, kerosene, and the like.

[0021] In some embodiments, the carbon dioxide source **104** supplies carbon dioxide gas fuel generator **102** that is captured and/or extracted from ambient air where the carbon dioxide source **106** is disposed. The hydrogen source **108** provides hydrogen that may be generated from water using one or more of electrolysis, radiolysis, and the like. In some embodiments, the hydrogen supplied to the fuel generator **102** may be generated using a hydrogen production system disclosed in Kutsch, U.S. Pat. No. 12,080,441, issued Sep. 3, 2024, and entitled “Hydrogen Production system and Method of Using Same”, which is incorporated herein in its entirety by reference. In some embodiments, the hydrogen source **108** may produce hydrogen from water and be integrated with the fuel generator **102**.

[0022] Referring also to FIGS. 2 and 3, in one embodiment, the fuel generator **102** comprises a monolithic block **140** having a carbon dioxide input port **142** that receives carbon dioxide from the carbon dioxide source **102**, a water input port **144** that receives water from the water source **106**, and a hydrogen input port **146** that receives hydrogen from the hydrogen source **108**. The monolithic block **140** has a bottom bounding surface **152** and top bounding surface **154** opposite one another and separated along direction parallel to a vertical axis **156**, a front bounding surface **158** and a rear bounding surface **160** opposite one another and separated along a direction parallel to a first horizontal axis **162**, and a first side bounding surface **164** and a second boundary **166** opposite one another and separated along a direction parallel to a second horizontal axis **168**. In some embodiments, one or more of the bounding surfaces **154**, **156**, **158**, and **160** may be substantially planar. In some cases, one or more of pairs of opposite bounding surfaces **152** and **154**, **158** and **160**, and **164** and **166** may be substantially parallel.

[0023] During operation, the fuel generator **102** is disposed so that the base portion **154** is proximate the ground relative to the top portion **156**. In this configuration, The carbon dioxide input port **142**, water input port **144**, and the hydrogen input port are **146** disposed on the top bounding surface **154** of the monolithic block and carbon dioxide, water, and hydrogen are supplied through these ports under pressure. These input materials are converted into intermediate products that have more mass per volume (i.e., are denser) than air and gravity facilitates the transport of such intermediate products through the fuel generator **102**. Gravity also facilitates separation of more dense intermediate products from less dense intermediate products and gravity causes more dense intermediate products to flow toward the bottom bounding surface **152**.

[0024] The fuel generator **102** also includes an intermediate material output port **170** and an intermediate material input port **172**. The intermediate material output port **170** is fluidically coupled to an input port of the compressor **112** and the intermediate material input port **172** is fluidically coupled to an output of the compressor **112**. As described above, the intermediate material flows from the output port **170**, through the compressor **112**, and is returned pressurized to the fuel generator **102** via the intermediate material input port **172**.

[0025] A fuel output port **174** is disposed proximate the bottom bounding surface **152** and fluidically coupled to the fuel reservoir **110** so that fuel generated by the fuel generator **102** may flow from the fuel output port **174** and into the fuel reservoir **110**.

[0026] In some embodiments, the fuel generator **102** may include one or more ports **176** through which probes (e.g., temperature, pressure, and the like) may be inserted to monitor operation of the fuel generator **102**, additional processing materials may be introduced, and byproducts generated by the fuel generator **102** may be evacuated, and the like.

[0027] FIG. 3 shows an exploded view of a portion **180** of the front bounding surface **158** of the fuel generator **102**. Referring also to FIG. 3, the fuel generator **102** is formed from a plurality of plates **182** stacked atop one another along the vertical axis **156** and bonded to one another to form the monolithic block **140** that forms the fuel generator **102**. Each plate **182** of the monolithic block **140** may be manufactured from stainless steel or another metal or metal alloy. In some embodiments, the plate **182** is manufactured from a conductive, non-corrosive material. In some embodiments, each plate **182** has a thickness of between approximately 1 millimeter to approximately 4 millimeters. In one embodiment, the plate **182** has a thickness of approximately 2.5 millimeters. In some embodiments, between 100 and 5,000 plates **182** may be stacked and fused together to form the monolithic block **140**. In other embodiments, more than 5,000 plates may be stacked and fused together to form the monolithic block **140**. It should be apparent that the monolithic block **140** may comprise more or fewer plates **182**. It should be apparent to one who has ordinary skill in the art that the plates **182** may be stacked along the first horizontal axis **162** or the second horizontal axis **168** in alternate embodiments. Further, a subset of the plates **182** that comprise the monolithic block **140** may be bonded (e.g., adhesively, heat fused, electron diffusion bonded, and the like) to one another to form a portion of the monolithic block **140** and thereafter a plurality of such portions may be bonded to one another to form the monolithic block **140**.

[0028] As discussed in greater detail below, each plate **182** may include one or more orifices or voids formed therein so that when the plates are fused together the orifices form one or more processing regions comprising one or more separated chambers, channels, conduits that guide intermediate products produced in one region into another region, ports, and other formations that facilitate production of fuel by the fuel generator **102**. Each processing region is shaped and configured to facilitate a particular type of chemical reaction or process necessary to transform the carbon dioxide, water, and hydrogen (or syngas and hydrogen) supplied via the input ports **142**, **144**, and **146**, respectively, into intermediate

products such as methanol, light olefins, oligomerized olefins, and the like and then into the fuel supplied from the output port 174.

[0029] In some embodiments, the plates 182 may be cut from sheets of material. Alternately, the plates 182 may be formed using an additive manufacturing process that deposits one or more layers of material atop one another to form each plate 182. In some embodiments, the plates 182 may be acid etched or CNC milled to form structures therein.

[0030] FIG. 4 shows the monolithic block 142 that comprises the fuel generator 102 with portions omitted to show the internal structure of the monolithic block 140. The monolithic block 142 includes a plurality of fluidically connected regions, wherein each region comprises a reactor for undertaking a corresponding chemical reactions or processes to develop intermediate products that result in the synthetic fuel output from the monolithic block 140. Referring to FIG. 4, in one embodiment, the monolithic block 142 includes a syngas generation region 200, a methanol generation region 202, an olefin generation region 204, an olefin oligomerization region 206, a hydrogenation region 208, and a fuel separation region 210.

[0031] FIG. 5 illustrates a plate 182a that may comprise at least a portion of the syngas generation region 200. Referring to FIG. 5, the plate 182a includes a plurality of orifices or voids 222 formed therein. The interior walls 224 of each of the plurality of the orifices 222 are filled with and/or coated with a suitable catalyst. When a plurality of plates 182a are stacked atop one another and bonded, the plurality of orifices 222 of form a plurality of catalyst coated channels and form a reaction portion of the syngas generation region 200. The syngas generation region 200 includes an electrolysis system (not shown) that separates a portion of the water supplied through the water input port 144 into hydrogen and oxygen. The oxygen generated by electrolysis may be released into the ambient environment. Such hydrogen and the carbon dioxide supplied through the carbon dioxide input port 142 pass through the catalyst coated channels formed by the plurality of orifices 222 and react to produce syngas (i.e., a mixture of hydrogen and carbon monoxide) using a reverse water-gas-shift reaction. The catalyst may include, for example, iron, nickel, a copper based material). In some embodiments, such reaction is endothermic and is undertaken at between approximately 400 and approximately 900 degrees Celsius and at a pressures of approximately 25 bar.

[0032] The plate 182a also includes an orifice or void 226. When the plurality of plates 182a are stacked atop one another, the plurality of orifices 226 of such plurality of plates 182 form a jacket section 228 that surrounds the reaction portion 220 of the syngas generation region 200. A portion of the water supplied through the water input port 144 flows through the jacket section 228 and draws heat generated by the chemical reactions that occur to create steam for the electrolysis process or other process (not shown). Such heated water may be transported to other regions of the monolithic block 140 to supply heat needed to facilitate any endothermic reactions and/or processes in such other regions or systems.

[0033] The plate 182a and other plates 182 that form the monolithic block 140 may include additional orifices 227. When the plates 182 are stacked and bonded to form the monolithic block 140, such additional orifices 227 may form conduits and/or channels to facilitate transport of fluids (e.g., hydrogen gas, water, and the like). In addition, some of the

channels formed by the orifices 227 may transport fluid proximate portions of the monolithic block 140 in which exothermic and endothermic reactions are undertaken to heat or cool, respectively, fluids flowing through such channels to facilitate the chemical reactions(s) in the monolithic block 140. In some cases, some of the channels formed by the plurality of the orifices 227 may be dwell channels through which material may flow to allow time for the material to stabilize before flowing into a subsequent process region of the monolithic block 140 or the output channel 172. In some embodiments, heating or chilling of materials in the monolithic block 140 may be accomplished by wrapping a section (or portion) of the exterior of the monolithic block 140 with a heating or cooling blanket or enclosure. Such blanket may provide heating or cooling inside and/or outside the monolithic block 140 as needed for processes that occur therein.

[0034] FIG. 6 illustrates a plate 182b that may comprise at least a portion of the methanol generation region 202. The plate 182b includes a reaction portion 230 that comprises a plurality of orifices 232 and the interior walls 234 of each of the plurality of orifices 232 are filled with catalyst pellets and/or coated with a catalyst. When the plurality of plates 182b are stacked and bonded, the plurality of orifices 232 combine to form a plurality of catalyst filled and/or coated channels that are fluidically coupled to the syngas generation region 200 and that comprise a reaction portion 230 of the methanol generation region 202. The syngas formed in the syngas generation region 200 and a portion of the hydrogen supplied through the hydrogen input port 146 flow into the plurality of catalyst coated reaction channels formed by the plurality of the orifices 232 and react to form methanol. The reaction portion 230 of the methanol generation region 202 may be, in some cases, a multitubular fixed bed arrangement. The catalysts used in the reaction portion 230 of the methanol generation region 202 may include, for example, a copper/zinc oxide/alumina catalyst and the reactions therein may be undertaken at approximately 226 degrees Celsius. The hydrogen to syngas may be supplied to such reaction portion 230 in a ratio of 2.0.

[0035] Each plate 182b also includes a void 236 and when the plurality of plates 182b are stacked and bonded together, the void 236 forms a preheat gas jacket 238 that surrounds the water jacket 238 and the reaction portion 230 of the methanol generation region 202. In some embodiments, any gas or fluid that requires heating may flow through preheat jacket 238 and be heated.

[0036] In some embodiments, the syngas generation region 200 may be omitted from the monolithic block 140 and syngas from an external syngas source (not shown) may be supplied through the port 104 instead of carbon dioxide. Such syngas flows directly into the channels formed by the plurality of the orifices 232 that form the reaction portion 234 of the methanol generation region 202 with the portion of the hydrogen gas to produce methanol.

[0037] Methanol generated in the reaction channels formed by the orifices 232 of the methanol generation region 202 flows via a conduit or channel 240 into a methanol to an olefin reactor 242 of the olefin generation region 204. FIG. 7 illustrates a plate 182c that may be used to create the conduit 240 within the monolithic block 140. The plate 182c includes a void 244. When a plurality of plates 182c are stacked atop one another and bonded, a plurality of the voids 244 in such plates 182c combine to form the conduit section

240. Other conduits to carry fluid through regions of the monolithic block **140** may be formed in a similar manner.

[0038] FIG. 8 illustrates a plate **182d** that may be used to form at least a portion of the olefin generation region **204**. Referring to FIG. 8, the plate **182d** includes a methanol to olefin reaction section **246**, one or more channel portions **248**, and an olefin separation section **250**. When a plurality of plates **182d** are stacked and bonded, a plurality of the olefin reaction section **246** of such plates **182d** combine to form the methanol to olefin reactor **242** and a plurality of the olefin separation sections **250** combine to form an olefin separator **252**. A plurality of the one or more channel portions **248** combine to form one or more channels or conduits through which olefins generated in the olefin reactor **242** are transported to the olefin separator **252**. Thereafter, the olefins flow from the olefin separator **252** into the compressor **112** (FIG. 1) via the intermediate material output port **170**. The olefin reaction section **246** includes microporous (e.g., pore size less than 2 nanometers) zeolite molecular sieve catalysts such as, for example, ZSM-5, ZSM-11, MCM-22, and the like and the reaction is undertaken at approximately 450 degrees Celsius and approximately 2 bar pressure. Such reaction is a high single-pass conversion of 95% of the reactants supplied and produces ethylene, 1-butene, and 1-pentene. Backpressure causes the olefins to flow from the olefin reactor **242** into the olefin separator **252**. The olefin separator **252** recirculates molecules that are not sufficiently long through the olefin reactor **242**.

[0039] The compressor **112** compresses the olefins and the compressed olefins flow through intermediate material input port **172** and into a first olefin oligomerizer **260** and are oligomerized. Shorter chain length oligomerized olefins flow from the first olefin oligomerizer **260** to a second olefin oligomerizer **262** via a conduit **264** before oligomerized olefins having longer chain lengths. Oligomerized olefins having shorter chain lengths in the second olefin oligomerizer **262** return to the first olefin oligomerizer **260** via a conduit **266**. The first olefin oligomerizer **260** and the second olefin oligomerizer **262** each facilitate reactions that extend the hydrocarbon chains of the olefins therein via oligomerization. Oligomerized olefins that reach a desired chain length (i.e., hydrocarbon length) flow from the second olefin oligomerizer **260** into a conduit **268**. It should be apparent to one who has ordinary skill in the art that that chain length of the oligomerized olefins is related to a boiling point thereof. In some embodiments, flows between the first and second olefin oligomerizers **260**, **262** may be undertaken in a manner similar to those that occur in a distillation column.

[0040] FIG. 9 shows a plate **182e** that may be used to form at least portions of the first oligomerizer **260** and the first and second conduits **264**, **266**. Referring to FIG. 9, the plate **182e** includes oligomerizer reaction section **270**, a first orifice **272**, and a second orifice **274**. When a plurality of the plates **182e** are stacked atop one another, a plurality of oligomerizer reaction sections **270** combine to form the first oligomerizer **260**, a plurality of the orifices **272** combine to form the first conduit **262**, and a plurality of the second orifices **274** combine to form the second conduit **266**. The second oligomerizer **262** may be formed in a similar manner. The first oligomerizer reaction section **270** may include catalysts such as H-Beta Zeolite to facilitate reactions that convert dimers and trimers of C2 and C4 products to C6+ olefins in the presence of catalyst. Such reactions are exo-

thermic and may be undertaken at approximately 299 degrees Celsius at a pressure of 21 bar.

[0041] A second oligomerizer reaction section of the **270** of the second oligomerizer **262** may include a catalyst such as Amberlyst (an acid catalyst made from styrene-divinylbenzene resin with sulfonic acid functional groups) to facilitate a reaction undertaken at approximately 163 degrees Celsius at 9.6 bar. Such reaction increases the yield to C9 and C18 compounds.

[0042] In some embodiments, the first and second oligomerizer reaction sections **270** of the first and second oligomerizers **260**, **262** are fixed-bed designs having pellets of catalyst arranged randomly or in order in tubes therein. In some cases, such catalysts may be coated onto a honeycomb structure.

[0043] As noted above, oligomerized olefins having sufficient chain length (e.g., via gravity) from the second oligomerizer **262** via the conduit **268** into the hydrogenation region **208**. In some embodiments, such chain length may be between C8 to C16, and more particularly between C10 and C14 (that corresponds to Jet-A and Jet-A1 fuel). The hydrogenation region **208** comprises hydrogenator **280** fluidically coupled to the conduit **268** and the olefins are hydrogenated in the hydrogenator **280** using hydrogen supplied through the hydrogen input port **146**. FIG. 10 illustrates a plate **182f** that may be used to form at least a portion of the hydrogenation region **208**. The plate **182f** includes a hydrogenator reaction portion **282** and a first orifice **284**, a second orifice **286**, and a third orifice **288** fluidically coupled to the hydrogenator reaction portion **282**. When a plurality of plates **182e** are stacked atop one another and bonded, a plurality of hydrogenator reaction portions **282** combine to form the hydrogenator **280**. Further, a plurality of the orifices **284** combine to form a channel that is fluidically connected to the conduit **268**, a plurality of the orifices **286** combine to form a channel that is fluidically connected to the hydrogen input port **146**, and a plurality of the orifices **288** combine to form a channel that is fluidically connected to a fuel output conduit **290** of the hydrogenator **280** (and thus the hydrogenation region **208**). The hydrogenator reaction portion **282** may be a fixed bed, e.g. a multitubular fixed bed structure, and that include a palladium on alumina catalyst to facilitate a reaction at 400 degrees Celsius at 9 bar total pressure. In some embodiments, 70% of the total pressure is supplied by, for example, the partial pressure of the hydrogen gas.

[0044] Fuel flows from the fuel output conduit **290** to the fuel separation region **210**. The fuel separation region **210** comprises a fuel separator **292** and a fuel blender **294**. The fuel separator **292** is fluidically coupled to the conduit **290** and also to the fuel blender **294** via a conduit **296**. The fuel blender **294** is coupled to the fuel output **174** through which fuel produced by the fuel generator **102** is supplied to the fuel reservoir **110**.

[0045] FIG. 11 shows a plate **182e** that may be used to form at least a portion of the fuel separation region **210**. Referring to FIG. 11, the plate **182e** includes a fuel separation section **298** and a fuel blending section **300** and a channel **302** therebetween. The plate **182e** also includes an orifice **302** fluidically coupled to the fuel separation section **298** and an orifice **304** fluidically coupled to the fuel blending section. When a plurality of the plates **182e** are stacked and bonded, the plurality of fuel separation sections **298** combine to form the fuel separator **292**, the plurality of

fuel blending sections combine to form the fuel blender **294**, and the plurality of channels **302** combine to form the conduit **296**. Further, the orifices **302** combine to form a channel fluidically coupled to the fuel output conduit **290** from the hydrogenator **280** and the orifices **304** combine to form a channel fluidically coupled to the fuel output port **174** of the fuel generator **102**. In some embodiments, the fuel separator **292** may be configured as a fractionator or a fractional distillation column. In some embodiments, the fuel separator **292** may be external to the block **140** and mixed fuel may flow from the output port **174** through the external fuel separator, and fuel separated by the external fuel separator may be supplied to the fuel reservoir **110**.

[0046] The fuel generator **102** comprising the single, unitary, bonded monolithic block **140** may reduce the complexity and costs associated to conventional fuel generation systems or factories. The reduction in complexity and costs may be realized at least because the separate reaction, heating, cooling tanks and the like, and associated piping and fitting components of such factories may be compressed into a single unit such as the monolithic block **140** described herein.

[0047] While particular embodiments of the present invention have been illustrated and described, it would be apparent to those skilled in the art that various other changes and modifications can be made and are intended to fall within the spirit and scope of the present disclosure. Furthermore, although the present disclosure has been described herein in the context of a particular implementation in a particular environment for a particular purpose, those of ordinary skill in the art will recognize that its usefulness is not limited thereto and that the present disclosure may be beneficially implemented in any number of environments for any number of purposes. Accordingly, the claims set forth below should be construed in view of the full breadth and spirit of the present disclosure as described herein.

[0048] All references, including publications, patent applications, and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.

[0049] The use of the terms “a” and “an” and “the” and similar references in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context. Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. All methods described herein can be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context. The use of any and all examples, or exemplary language (e.g., “such as”) provided herein, is intended merely to better illuminate the disclosure and does not pose a limitation on the scope of the disclosure unless otherwise claimed. No language in the specification should be construed as indicating any non-claimed element as essential to the practice of the disclosure.

[0050] Numerous modifications to the present disclosure will be apparent to those skilled in the art in view of the foregoing description. It should be understood that the

illustrated embodiments are exemplary only, and should not be taken as limiting the scope of the disclosure.

1. A fuel generator, comprising:

- a monolithic block comprising a plurality of plates stacked and bonded together;
 - a first input port disposed on the monolithic block, wherein the first input port is coupled to a source of hydrogen gas;
 - a second input port disposed on the monolithic block, wherein the second input port is coupled to a source of carbon dioxide or syngas; and
 - an output port disposed on the monolithic block, wherein the output port is coupled to a fuel reservoir;
- wherein the plurality of plates form a plurality of reaction regions, wherein at least a portion of the plurality of reaction regions convert one of the carbon dioxide or syngas and hydrogen into a hydrocarbon fuel, wherein the hydrocarbon fuel is supplied from the output port; and

wherein a first subset of the plurality of plates are bonded to form at least a portion of a methanol generation region, a second subset of the plurality of plates are bonded to form at least a portion of an olefin generation region, a third subset of the plurality of plates are bonded to form at least a portion an oligomerization region, and a fourth subset of the plurality of plates are bonded to form a hydrogenation region.

2. The fuel generator of claim 1, wherein the second input port is coupled to the source of carbon dioxide and the plurality of reaction regions includes a syngas generation region that converts carbon dioxide and the hydrogen gas into syngas.

3. (canceled)

4. The fuel generator of claim 1, wherein methanol is produced from the syngas in the methanol generation region.

5. The fuel generator of claim 4, wherein olefins are produced in the olefin generation region from the methanol produced in the methanol generation region.

6. The fuel generator of claim 5, wherein oligomerized olefins are produced in the oligomerization region from the olefins produced in the olefin generation region.

7. The fuel generator of claim 6, further including a compressor coupled to the olefin generation region and the oligomerization region, wherein olefins produced in the olefin generation region are compressed by the compressor before flowing into the oligomerization region.

8. The fuel generator of claim 7, wherein the compressor is external to the monolithic block.

9. The fuel generator of claim 7, wherein the oligomerization region comprises a plurality of connected oligomerization reactors.

10. The fuel generator of claim 7, wherein oligomerized olefins are separated in accordance with density in the oligomerization region.

11. A method for generating fuel comprising:

- providing a monolithic block, wherein the monolithic block is formed from a plurality of plates stacked and bonded together to form a plurality of reaction regions, and the monolithic block includes a first input port, a second input port, and an output port, wherein providing the monolithic block comprises:

- bonding a first subset of the plurality of plates to form at least a portion of a methanol generation region,

bonding a second subset of the plurality of plates to form at least a portion of an olefin generation region, bonding a third subset of the plurality of plates to form at least a portion an oligomerization region, and bonding a fourth subset of the plurality of plates to form a hydrogenation region;

supplying hydrogen gas to the first input port;

supplying one of carbon dioxide or syngas to the second input port;

converting the hydrogen gas and one of the carbon dioxide or syngas in the plurality of reaction region into a hydrocarbon fuel; and

supplying the hydrocarbon fuel from the output port.

12. The method of claim **11**, wherein carbon dioxide is supplied to the second input port and the plurality of reaction regions includes a syngas generation region, further including converting the carbon dioxide and the hydrogen gas into syngas in the syngas generation region.

13. (canceled)

14. The method of claim **11**, further including producing methanol from the syngas in the methanol generation region.

15. The method of claim **14**, further including producing olefins in the olefin generation region from the methanol produced in the methanol generation region.

16. The method of claim **15**, further including producing oligomerized olefins in the oligomerization region from the olefins produced in the olefin generation region.

17. The method of claim **16**, further including compressing the olefins produced in the olefin generation region before flowing into the oligomerization region.

18. The method of claim **17**, further including coupling monolithic block to a compressor external to the monolithic block and operating the compressor to compress the olefins.

19. The method of claim **17**, wherein the oligomerization region comprises a plurality of connected oligomerization reactors.

20. The method of claim **17**, further including separating the oligomerized olefins in accordance with density in the oligomerization region.

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