used to create and maintain these plasmas. Furthermore, conversion of light output from plasmas is often associated with energy losses where, for example, low energy light (*e.g.*, infrared light) is below the bandgap of photovoltaics and therefore lost, to the system. Moreover, plasma light output to photovoltaic is often impeded by a window between reaction cells and the photovoltaic that is susceptible to certain deformations and material accumulation thereon resulting in lower delivery of light to the photovoltaic and energy loss from the system.

SUMMARY

In an aspect, the present disclosure refers to a power generation system comprising:

a) at least one vessel capable of a maintaining a pressure below atmospheric comprising a reaction chamber;

b) two electrodes configured to allow a molten metal flow therebetween to complete a circuit;

c) a power source connected to said two electrodes to apply an ignition current therebetween when said circuit is closed;

d) a plasma generation cell (e.g., glow discharge cell) to induce the formation of a first plasma from a gas delivered thereto; wherein effluence of the plasma generation cell is directed towards the circuit (e.g., the molten metal, the anode, the cathode, an electrode submerged in a molten metal reservoir);

wherein when current is applied across the circuit, the effluence of the plasma generation cell undergoes a reaction to producing a second plasma and reaction products; and

e) a power adapter comprising a thermophotovoltaic converter configured to convert and/or transfer energy from the second plasma into mechanical, thermal, and/or electrical energy;

wherein energy from the second plasma is absorbed in a blackbody radiator to produce blackbody radiation and said blackbody radiation is converted in the thermophotovoltaic converter.

In an example, the present disclosure is directed to power systems that generates at least one of electrical energy and thermal energy comprising:

at least one vessel capable of a maintaining a pressure below atmospheric;

reactants capable of undergoing a reaction that produces enough energy to form a plasma in the vessel comprising:

a) a mixture of hydrogen gas and oxygen gas, and/or

water vapor, and/or

a mixture of hydrogen gas and water vapor;

b) a molten metal;

a mass flow controller to control the flow rate of at least one reactant into the vessel;

a vacuum pump to maintain the pressure in the vessel below atmospheric pressure when one or more reactants are flowing into the vessel;

a molten metal injector system comprising at least one reservoir that contains some of the molten metal, a molten metal pump system (*e.g.*, one or more electromagnetic pumps) configured to deliver the molten metal in the reservoir and through an injector tube to provide a molten metal stream, and at least one non-injector molten metal reservoir for receiving the molten metal stream;

at least one ignition system comprising a source of electrical power or ignition current to supply electrical power to the at least one stream of molten metal to ignite the reaction when the hydrogen gas and/or oxygen gas and/or water vapor are flowing into the vessel;

a reactant supply system to replenish reactants that are consumed in the reaction;

a power converter or output system to convert a portion of the energy produced from the reaction (*e.g.*, light and/or thermal output from the plasma) to electrical power and/or thermal power.

Power systems (herein referred to as "SunCells") of the present disclosure may comprise:

a) at least one vessel capable of a maintaining a pressure below atmospheric comprising a reaction chamber;

b) two electrodes configured to allow a molten metal flow therebetween to complete a circuit;

c) a power source connected to said two electrodes to apply an ignition current therebetween when said circuit is closed;

d) a plasma generation cell (e.g., glow discharge cell) to induce the formation of a first plasma from a gas delivered thereto; wherein effluence of the plasma generation cell is directed towards the circuit (e.g., the molten metal, the anode, the cathode, an electrode submerged in a molten metal reservoir);

wherein when current is applied across the circuit, the effluence of the plasma generation cell undergoes a reaction to producing a second plasma and reaction products; and

e) a power adapter comprising a thermophotovoltaic converter configured to convert and/or transfer energy from the second plasma into mechanical, thermal, and/or electrical energy;

wherein energy from the second plasma is absorbed in a blackbody radiator to produce blackbody radiation and said blackbody radiation is converted in the thermophotovoltaic converter. In some examples, the power adapter is a plurality of thermophotovoltaic adapters. The thermophotovoltaic adapter may comprise a photovoltaic converter in a geodesic dome, wherein the photovoltaic converter may comprise a receiver array (*e.g.*, a dense receiver array) comprised of triangular elements; and

wherein each triangular element comprises a plurality of concentrator photovoltaic cells capable of converting the blackbody radiation into electricity. In some examples, the positively biased electrode of the two electrodes is, comprises, or is connected to the blackbody radiator. In various implementations, the photons produced from the plasma having an energy less than the bandgap of the photovoltaic cells (*e.g.*, infrared) are reflected back towards the plasma generation cell (*e.g.*, towards the blackbody radiator).

Typically, light output from the reaction cell and/or blackbody radiator is collected in a photovoltaic for electrity generation and/or a blackbody radiator which outputs energy thermally and optically, each of which may be individually collected. In some examples, the system may comprise a PV window between a reaction cell comprising the second plasma and the thermophotovoltaic converter. In order to maintain energy generation, the molten metal (*e.g.*, tin) may not wet the PV window by levarging materials, systems, and methods of the present disclosure. In some examples, the gas may be a reaction mixture that does not oxidize tin or provides minimal oxidation to tin (*e.g.*, less than 10% or less than 5% or less than 1% of the molten metal in the system is not oxidized with the gas provided to the system for 12 hours). In various implementations, the PV window may comprise (or predominantly comprises) flat surfaces, the power adapter comprises a photovoltaic (PV) converter, and the PV converter comprises a flat dense receiver array panel to receive the plasma emission through the PV window with a geometry matching the PV window. These configurations may minimize reflectance of low energy light not absorbed by the photovoltaic but directed back towards the reaction cell for light recycling. In some examples, the PV window comprises at least one of quartz, sapphire, aluminum oxynitride, and MgF_2.

The high intensity environment generated by the system has profound effect on the system components. Relative dimensions, geometries, and placements of each component are all implicated in the creation of steady state plasmas. These components should be balanced in order to keep the system capable of generating the first and second plasmas. Typically, the each electrode of the two electrodes comprises a molten metal reservoir and an electrical feedthrough to supply the current only to the molten metal therein and thereby supply the ignition current. In various implementations, the system may comprise a reaction cell chamber connected to the reservoirs wherein the walls of at least one of the reservoirs and the reaction cell chamber are electrically isolated by at least one of a ceramic coating and a liner. In some examples, at least one of the reservoirs and the reaction cell chamber are thermally insulated by a liner. The liner may be or comprise carbon and/or tungsten optionally coated a ceramic coating. In other examples, the reservoirs are electrically isolated from each othr by an electrical break in at least one of the reserviors.

The molten metal flowing between the two electrodes may be formed from dual molten metal injection systems independently in fluid communication with one or more molten metal reservoirs comprising the molten metal;

wherein each molten metal injection system comprises an electromagnetic pump and a nozzle, wherein each electromagnetic pump flows molten metal through the nozzle to form a stream of molten metal;

wherein said electrodes are in communication with the molten metal streams thereby forming dual molten metal streams of opposite polarity; and

wherein said complete circuit is formed by intersection the dual molten metal streams. The reservoirs may comprise an electrical break to electrically isolate the electrodes from each other. Alignment of the molten metal stream, and in particular, alignment during operation is important to maintain plasma generation. To achieve such alignment, the system may comprise a flexible element and at least one actuator to tilt the injector electrode of the reservoir to cause alignment of the molten metal streams. In various implementations, a reservoir may comprise a baseplate supported by a plurality of supports wherein the at least one actuator to tilt the injector electrode of the reservoir lengthens or shortens at least one support. In certain examples, the flexible element may comprise a stationary frame on one end and a moveable frame one the opposite end, and further comprises at least one actuator attached to the movable frame and the frame wherein the actuators contract on one side and expand on opposing sides of the flexible element to cause the injector to tilt. The flexible element may comprise a bellows.

Plasma generation involving molten metal often results in coating the PV window (*e.g.*, with molten metal, with an oxide of the molten metal) thereby preventing optical transmision to the photovoltaic converter. By minimizing this accumulation, the systems of the present disclosure may be used for many applications aside from photovoltaic conversion. For example, in some examples, the dual molten streams may intersect in a chamber comprising a window and light produced from the second plasma or the blackbody radiation exits the window to heat a load. The load may be an oven chamber (or air/water/steam therein) heated by the light produced from the second plasma or the blackbody radiation. In some examples, the second plasma reaction occurs in a reaction chamber comprising a PV window;

the molten metal or oxidized molten metal is removed from the PV and:

a) the PV window comprises at least one of quartz, sapphire, aluminum oxynitride, CaF_2, and MgF_2;

b) the PV window is heated above the melting point of an oxide of the molten metal (*e.g.*, tin oxide);

c) hydrogen reduction of the oxide of the molten metal occurs by flowing hydrogen gas into the reaction chamber at a pressure sufficient to achieve said hydrogen reduction; and/or

d) the PV window has molten metal injected onto its surface during generation of the second plasma (*e.g.*, from an electromagnetic pump).

In some examples, the system comprises a PV window and at least one thermal absorber wherein optical power from the second plasma reaction is transferered through the PV window to the thermal absorber by radiative power transfer, and said thermal absorber transmits thermal power from said radiative power transfer. In some examples, the system comprises or is a water boiler heated by the thermal power from the thermal absorber. In some examples, the system comprises an air heat exchanger heated by the thermal power from the thermal absorber. In some examples, the system is surrounded by an outer chamber, which may be filled a load such as water. During operation, energy from the second plasma may be transferred to the load thermally and/or optically.

Systems for removing a molten metal oxide (*e.g.*, tin oxide) from a PV window are also provided. These systems may comprise;

a source of a deaccumulation material, wherein said deaccumulation material is directed towards said PV window; and

said deaccumulation material is hydrogen gas or molten metal of the molten metal oxide.

Methods are also provided. The method may, for example, generate power or produce light, or product a plasma. In some examples, the method comprises:

a) electrically biasing a molten metal;

b) directing the effluence of a plasma generation cell (*e.g.*, a glow discharge cell) to interact with the biased molten metal and induce the formation of a plasma. In certain implementations, the effluence of the plasma generation cell is generated from a hydrogen (H_2) and oxygen (O_2) gas mixture passing through the plasma generation cell during operation.

Methods are also provided. For example, the method may comprise:

a) forming a first plasma in a glow discharge cell from a gas directed thereto;

b) creating an electrically biased molten metal stream;

c) directing the effluence from the glow discharge cell towards the electrically biased molten metal stream to form a second plasma that produces ultraviolet, visible, and/or infrared light.

The light may be used to heat a load and/or in a photovoltaic converter to generate electricity. In some examples, the gas in the plasma generation cell comprises a mixture of hydrogen (H_2) and oxygen (O_2).

The disclosure also embraces methods for removing a molten metal oxide (*e.g.*, tin oxide) from a PV window. The method may comprise, for example, directing a deaccumulation material towards said PV window;

wherein said deaccumulation material is hydrogen gas or molten metal of the molten metal oxide. In some examples, the deaccumulation material is molten metal (*e.g.*, tin) wherein the window is exposed a plasma and the molten metal is directed onto the window at a rate to prevent or decrease structural deformations of the window associated with overheating (e.g., warping, cracking, decreases in transparency) or undergoing any structural deformations associated with overheating (e.g., warping, cracking).

In some examples, the gas in the plasma generation cell is a mixture of hydrogen (H_2) and oxygen (O_2). For example, the relative molar ratio of oxygen to hydrogen is from 0.01-50 (*e.g.* from 0.1-20, from 0.1-15, less than 10, less than 5, less than 2, etc.). In some examples, the relative flow rate of oxygen to hydrogen is from 0.01-50 by volume at room temperature (*e.g.* from 0.1-20, from 0.1-15, less than 10, less than 5, less than 2, etc.). In certain implementations, the molten metal is gallium or tin. In some examples, the reaction products have at least one spectroscopic signature as described herein (*e.g.*, those described herein and in the Appendix or SubAppendix of U.S. App. No. 62/236,198, filed August 23, 2021, which is hereby incorporated by reference in its entirety and, in particular, the spectroscopic measurements therein such as EPR and Raman of material produced by systems of the present disclosure and collected following thereof). In various examples, the second plasma is formed in a reaction cell, and the walls of said reaction cell comprise a liner having increased resistance to alloy formation with the molten metal and the liner and the walls of the reaction cell have a high permability to the reaction products (*e.g.* stainless-steel such as 347 SS such as 4130 alloy SS or Cr-Mo SS, nickel, Ti, niobium, vanadium, iron, W, Re, Ta, Mo, niobium, and Nb(94.33 wt%)-Mo(4.86 wt%)-Zr(0.81 wt%)). The liner may be made of a crystalline material (*e.g.*, SiC, BN, quartz) and/or a refractory metal such as at least one of Nb, Ta, Mo, or W. In certain examples, the second plasma is formed in a reaction cell, wherein the walls reaction cell chamber comprise a first and a second section,

the first section composed of stainless steel such as 347 SS such as 4130 alloy SS or Cr-Mo SS, nickel, Ti, niobium, vanadium, iron, W, Re, Ta, Mo, niobium, and Nb(94.33 wt%)-Mo(4.86 wt%)-Zr(0.81 wt%);

the second section comprising a refractory metal different than the metal in the first section;

wherein the union between the different metals is formed by a lamination material (*e.g.*, a ceramic such as BN).

The power system may comprise a gas mixer for mixing the hydrogen and oxygen gases and/or water molecules and a hydrogen and oxygen recombiner and/or a hydrogen dissociator. In some examples, the the hydrogen and oxygen recombiner comprises a plasma cell. The plasma cell may comprise a center positive electrode and a grounded

tubular body counter electrode wherein a voltage (*e.g.* ,a voltage in the range of 50 V to 1000 V) is applied across the electrodes to induce the formation of a plasma from a hydrogen (H_2) and oxygen (O_2) gas mixture. In some examples, the hydrogen and oxygen recombiner comprises a recombiner catalytic metal supported by an inert support material. In certain implementations, the gas mixture supplied to the plasma generation cell to produce the first plasma comprises a non-stoichiometric H_2/O_2 mixture (*e.g.*, an H_2/O_2 mixture having less than 1/3 mole % O_2 or from 0.01% to 30%, or from 0.1% to 20%, or less than 10%, or less than 5%, or less than 3% O_2 by mole percentage of the mixture) that is flowed through the plasma cell (*e.g.*, a glow discharge cell) to create a reaction mixture capable of undergoing the reaction with sufficient exothermicity to produce the second plasma. A non-stoichiometric H_2/O_2 mixture may pass through the glow discharge to produce an effluence of atomic hydrogen and nascent H_2O (*e.g.*, a mixture having water at a concentration and with an internal energy sufficient to prevent formation of hydrogen bonds);
the glow discharge effluence is directed into a reaction chamber where the ignition current is supplied between two electrodes (*e.g.*, with a molten metal passed therebetween), and upon interaction of the effluence with the biased molten metal (*e.g.*, gallium or tin), the reaction between the nascent water and the atomic hydrogen is induced, for example, upon the formation of arc current.

The power system may comprise at least one of the reaction chamber (*e.g.* where the nascent water and atomic hydrogen undergo the second plasma forming reaction) and/or reservoir comprising at least one refractory material liner that is resistant to forming an alloy with the molten metal. The inner wall of the reaction chamber may comprise a ceramic coating, a carbon liner lined with a W, Nb, or Mo liner, lined with W plates. In some embodimens, the reservoir comprises a carbon liner and the carbon is covered by the molten metal contained therein. In various implementations, the reaction chamber wall comprises a material that is highly permeable to the reaction product gas. In various examples, the reaction chamber wall comprises at least one of stainless steel (*e.g.*, Mo-Cr stainless steel), niobium, molybdenum, or tungsten.

The power system may comprise a a condenser to condense molten metal vapor and metal oxide particles and vapor and returns them to the reaction cell chamber. In some examples, the power system may further comprise a vacuum line wherein the condenser comprises a section of the vacuum line from the reaction cell chamber to the vacuum pump that is vertical relative to the reaction cell chamber and comprises an inert, high-surface area filler material that condenses the molten metal vapor and metal oxide particles and vapor and returns them to the reaction cell chamber while permitting the vacuum pump to maintain a vacuum pressure in the reaction cell chamber.

The power system may comprise a blackbody radiator and a window to output light from the blackbody radiator. Such examples may be used to generate light (*e.g.*, used for lighting).

In some examples, the power system may further comprise a gas mixer for mixing the hydrogen and oxygen gases and a hydrogen and oxygen recombiner and/or a hydrogen dissociator. For example, the power system may comprise a hydrogen and oxygen recombiner wherein the hydrogen and oxygen recombiner comprises a recombiner catalytic metal supported by an inert support material.

The power system may be operated with parameters that maximize reactions, and specifically, reactions capable of outputting enough energy to sustain plasma generation and net energy output. For example, in some examples, the pressure of the vessel during operation is in the range of 0.1 Torr to 50 Torr. In certain implementations, the hydrogen mass flow rate exceeds that of the oxygen mass flow rate by a factor in the range of 1.5 to 1000. In some examples, the pressure may be over 50 Torr and may further comprise a gas recirculation system.

In some examples, an inert gas (*e.g.*, argon) is injected into the vessel. The inert gas may be used to prolong the lifetime of certain *in situ* formed reactants (such as nascent water).

The power system may comprise a water micro-injector configured to inject water into the vessel such that the plasma produced from the energy output from the reaction comprises water vapor. In some examples, the micro-injector injects water into the vessel. In some examples, water is flowed towards the biased crossing molten streams as a vapor. In some examples, water is produced in the glow discharge cell. In some examples, water vapor is present in the gas mixture. In some examples, humid air is used in gas resulting in delivery of water to the reaction cell. In some examples, the H_2 molar percentage for generation of the second plasma is in the range of 1.5 to 1000 times the molar percent of the water vapor (*e.g.*, the water vapor injected by the micro-injector, the water present in the effluence of the glow discharge cell).

The power system may further comprise a heater to melt a metal (*e.g.*, tin or gallium or silver or copper or combinations thereof) to form the molten metal. The power system may further comprise a molten metal recovery system configured to recover molten metal after the reaction comprising a molten metal overflow channel which collects overflow from the non-injector molten metal reservoir.

The molten metal injection system may further comprise electrodes in the molten metal reservoir and the non-injection molten metal reservoir; and the ignition system comprises a source of electrical power or ignition current to supply opposite voltages to the injector and non-injector reservoir electrodes; wherein the source of electrical power supplies

current and power flow through the stream of molten metal to cause the reaction of the reactants to form a plasma inside of the vessel.

The source of electrical power typically delivers a current electrical energy sufficient to cause the reactants to react to form the second plasma. In certain examples, the source of electrical power comprises at least one supercapacitor. In various implementations, the current from the molten metal ignition system power is in the range of 10 A to 50,000 A.

Typically, the molten metal pump system is configured to pump molten metal from a molten metal reservoir to a non-injection reservoir, wherein a stream of molten metal is created therebetween. In some examples, the molten metal pump system is one or more electromagnetic pumps and each electromagnetic pump comprises one of a

a) DC or AC conduction type comprising a DC or AC current source supplied to the molten metal through electrodes and a source of constant or in-phase alternating vector-crossed magnetic field, or

b) induction type comprising a source of alternating magnetic field through a shorted loop of molten metal that induces an alternating current in the metal and a source of in-phase alternating vector-crossed magnetic field.

In some examples, the circuit of the molten metal ignition system is closed by the molten metal stream to cause ignition to further cause ignition (*e.g.*, with an ignition frequency less than 10,000 Hz). The injector reservoir may comprise an electrode in contact with the molten metal therein, and the non-injector reservoir comprises an electrode that makes contact with the molten metal provided by the injector system.

In various implementations, the non-injector reservoir is aligned above (e.g., vertically with) the injector and the injector is configured to produce the molten stream orientated towards the non-injector reservoir such that molten metal from the molten metal stream may collect in the reservoir and the molten metal stream makes electrical contact with the non-injector reservoir electrode; and wherein the molten metal pools on the non-injector reservoir electrode. In certain examples, the ignition current to the non-injector reservoir may comprise:

a) a hermitically sealed, high-temperature capable feed though that penetrates the vessel;

b) an electrode bus bar, and

c) an electrode.

The ignition current density may be related to the vessel geometry for at least the reason that the vessel geometry is related to the ultimate plasma shape. In various implementations, the vessel may comprise an hourglass geometry (*e.g.*, a geometry wherein a

middle portion of the internal surface area of the vessel has a smaller cross section than the cross section within 20% or 10% or 5% of each distal end along the major axis) and oriented in a vertical orientation (*e.g.*, the major axis approximately parallel with the force of gravity) in cross section wherein the injector reservoir is below the waist and configured such that the level of molten metal in the reservoir is about proximal to the waist of the hourglass to increase the ignition current density. In some examples, the vessel is symmetric about the major longitudinal axis. In some examples, the vessel may an hourglass geometry and comprise a refractory metal liner. In some examples, the injector reservoir of the vessel having an hourglass geometry may comprise the positive electrode for the ignition current.

The molten metal may comprise at least one of tin, silver, gallium, silver-copper alloy, copper, or combinations thereof. In some examples, the molten metal has a melting point below 700 °C. For example, the molten metal may comprise at least one of bismuth, lead, tin, indium, cadmium, gallium, antimony, or alloys such as Rose's metal, Cerrosafe, Wood's metal, Field's metal, Cerrolow 136, Cerrolow 117, Bi-Pb-Sn-Cd-In-Tl, and Galinstan. In certain examples, at least one of component of the power generation system that contacts that molten metal (*e.g.*, reservoirs, electrodes) comprises, is clad with, or is coated with one or more alloy resistant material that resists formation of an alloy with the molten metal. Exemplary alloy resistant materials are W, Ta, Mo, Nb, Nb(94.33 wt%)-Mo(4.86 wt%)-Zr(0.81 wt%), Os, Ru, Hf, Re, 347 SS, Cr-Mo SS, silicide coated, carbon, and a ceramic such as BN, quartz, Si3N4, Shapal, AlN, Sialon, Al_2O_3, ZrO_2, or HfO_2. In some examples, at least a portion of the vessel is composed of a ceramic and/or a metal. The ceramic may comprise at least one of a metal oxide, quartz, alumina, zirconia, magnesia, hafnia, silicon carbide, zirconium carbide, zirconium diboride, silicon nitride, and a glass ceramic. In some examples, the metal of the vessel comprises at least one of a stainless steel and a refractory metal.

In some examples, the power generation system generates a water/hydrogen mixture to be directed towards the molten metal cell through a plasma generation cell. In these examples, the plasma generation cell such as a glow discharge cell induce the formation of a first plasma from a gas (*e.g.*, a gas comprising a mixture oxygen and hydrogen); wherein effluence of the plasma generation cell is directed towards the any part of the molten metal circuit (*e.g.*, the molten metal, the anode, the cathode, an electrode submerged in a molten metal reservoir). Upon interaction of the biased molten metal with this effluence, a second plasma (more energetic than that created by the plasma generation cell) may be formed. In these examples, the plasma generation cell may be fed hydrogen (H_2) and oxygen mixtures (O_2) having a molar excess of hydrogen such that the effluence comprises atomic hydrogen (H) and water (H_2O). The water in the effluence may be in the form of nascent water, water sufficiently energized and at a concentration such that it is not

hydrogen bonded to other components in the effluence. This effluence may proceed in a second more energetic reaction involving the H and HOH that forms a plasma that intensifies upon interaction with the molten metal and a supplied external current through at least one of the molten metal and the plasma that may produce additional atomic hydrogen (from the H_2 in the effluence) to further propagate the second energetic reaction.

In some examples, the power system may further comprise at least one heat exchanger (*e.g.*, a heat exchanger coupled to a wall of the vessel wall, a heat exchanger which may transfer heat to or from the molten metal or to or from the molten metal reservoir). In some examples, the heat exchanger comprises one of a (i) plate, (ii) block in shell, (iii) SiC annular groove, (iv) SiC polyblock, and (v) shell and tube heat exchanger. In certain implementations, the shell and tube heat exchanger comprises conduits, manifolds, distributors, a heat exchanger inlet line, a heat exchanger outlet line, a shell, an external coolant inlet, an external coolant outlet, baffles, at least one pump to recirculate the hot molten metal from the reservoir through the heat exchanger and return the cool molten metal to the reservoir, and one or more a water pumps and water coolant or one or more air blowers and air coolant to flow cold coolant through the external coolant inlet and shell wherein the coolant is heated by heat transfer from the conduits and exists the external coolant outlet. In some examples, the shell and tube heat exchanger comprise conduits, manifolds, distributors, a heat exchanger inlet line, and a heat exchanger outlet line comprising carbon that line and expand independently of conduits, manifolds, distributors, a heat exchanger inlet line, a heat exchanger outlet line, a shell, an external coolant inlet, an external coolant outlet, and baffles comprising stainless steel. The external coolant of the heat exchanger comprises air, and air from a microturbine compressor or a microturbine recuperator forces cool air through the external coolant inlet and shell wherein the coolant is heated by heat transfer from the conduits and exists the external coolant outlet, and the hot coolant output from the external coolant outlet flows into a microturbine to convert thermal power to electricity.

In some examples, the power system comprises at least one power converter or output system of the reaction power output comprises at least one of the group of a thermophotovoltaic converter, a photovoltaic converter, a photoelectronic converter, a magnetohydrodynamic converter, a plasmadynamic converter, a thermionic converter, a thermoelectric converter, a Sterling engine, a supercritical CO_2 cycle converter, a Brayton cycle converter, an external-combustor type Brayton cycle engine or converter, a Rankine cycle engine or converter, an organic Rankine cycle converter, an internal-combustion type engine, and a heat engine, a heater, and a boiler. The vessel may comprise a light transparent photovoltaic (PV) window to transmit light from the inside of the vessel to a photovoltaic converter and at least one of a vessel geometry and at least one baffle comprising a spinning window. The spinning window comprises a system to reduce gallium or tin oxide comprising at least one of a hydrogen reduction system and an electrolysis system. In some

examples the spinning window comprises or is composed of quartz, sapphire, aluminum oxynitride, magnesium fluoride, or combinations thereof. In several implementations, the spinning window is coated with a coating that suppresses adherence of at least one of gallium or tin and gallium or tin oxide. The spinning window coating may comprise at least one of diamond like carbon, carbon, boron nitride, and an alkali hydroxide. In some examples, the positive ignition electrode (*e.g.*, the top ignition electrode, the electrode displaced above the the other electrode) is closer to the window (*e.g.*, as compared to the negative ignition electrode) and the positive electrode emits blackbody radiation through the photovoltaic to the photovoltaic converter.

The power converter or output system may comprise a magnetohydrodynamic (MHD) converter comprising a nozzle connected to the vessel, a magnetohydrodynamic channel, electrodes, magnets, a metal collection system, a metal recirculation system, a heat exchanger, and optionally a gas recirculation system. In some examples, the molten metal may comprise silver. In examples with a magnetohydrodynamic converter, the magnetohydrodynamic converter may be delivered oxygen gas to form silver particles nanoparticles (*e.g.*, of size in the molecular regime such as less than about 10 nm or less than about 1 nm) upon interaction with the silver in the molten metal stream, wherein the silver nanoparticles are accelerated through the magnetohydrodynamic nozzle to impart a kinetic energy inventory of the power produced from the reaction. The reactant supply system may supply and control delivery of the oxygen gas to the converter. In various implementations, at least a portion of the kinetic energy inventory of the silver nanoparticles is converted to electrical energy in a magnetohydrodynamic channel. Such version of electrical energy may result in coalescence of the nanoparticles. The nanoparticles may coalesce as molten metal which at least partially absorbs the oxygen in a condensation section of the magnetohydrodynamic converter (also referred to herein as an MHD condensation section) and the molten metal comprising absorbed oxygen is returned to the injector reservoir by a metal recirculation system. In some examples, the oxygen may be released from the metal by the plasma in the vessel. In some examples, the plasma is maintained in the magnetohydrodynamic channel and metal collection system to enhance the absorption of the oxygen by the molten metal.

The molten metal pump system may comprise a first stage electromagnetic pump and a second stage electromagnetic pump, wherein the first stage comprises a pump for a metal recirculation system, and the second stage that comprises the pump of the metal injector system.

The reaction induced by the reactants produces enough energy in order to initiate the formation of a plasma in the vessel. These measurable spectroscopic signatures and reaction

cc) a hydrogen product comprising a hydrogen hydride ion that is magnetic and links flux in units of the magnetic in its bound-free binding energy region, and

dd) a hydrogen product wherein the high pressure liquid chromatography (HPLC) shows chromatographic peaks having retention times longer than that of the carrier void volume time using an organic column with a solvent comprising water wherein the detection of the peaks by mass spectroscopy such as ESI-ToF shows fragments of at least one inorganic compound.

In various implementations, the hydrogen product may be characterized similarly as products formed from various hydrino reactors such as those formed by wire detonation in an atmosphere comprising water vapor. Such products may:

a) comprise at least one of a metal hydride and a metal oxide further comprising hydrogen wherein the metal comprises at least one of Zn, Fe, Mo, Cr, Cu, and W and the hydrogen comprises H;

b) comprise an inorganic compound M_xX_y and H_2 wherein M is a metal cation and X is an anion and at least one of the electrospray ionization time of flight secondary ion mass spectrum (ESI-ToF) and the time of flight secondary ion mass spectrum (ToF-SIMS) comprises peaks of $M(M_xX_yH(1/4)_2)n$ wherein n is an integer;

c) be magnetic and comprise at least one of a metal hydride and a metal oxide further comprising hydrogen wherein the metal comprises at least one of Zn, Fe, Mo, Cr, Cu, W, and a diamagnetic metal, and the hydrogen is H(1/4), and

d) comprise at least one of a metal hydride and a metal oxide further comprising hydrogen wherein the metal comprises at least one of Zn, Fe, Mo, Cr, Cu, W, and a diamagnetic metal and H is H(1/4) wherein the product demonstrates magnetism by magnetic susceptometry.

In some examples, the hydrogen product formed by the reaction comprises the hydrogen product complexed with at least one of (i) an element other than hydrogen, (ii) an ordinary hydrogen species comprising at least one of H^+, ordinary H_2, ordinary H^-, and ordinary H_3^+, an organic molecular species, and (iv) an inorganic species. In some examples, the hydrogen product comprises an oxyanion compound. In various implementations, the hydrogen product (or a recovered hydrogen product from examples comprising a getter) may comprise at least one compound having the formula selected from the group of:

a) MH, MH_2, or M_2H_2, wherein M is an alkali cation and H or H_2 is the hydrogen product;

and the hydrogen content H_m of the compound comprises at least one of the hydrogen products; and

z) $\left(MH_mM'X'\right)_n^+ \; nX^-$ wherein m and n are each an integer, M and M' are each an alkali or alkaline earth cation, X and X' are a singly or double negatively charged anion, and the hydrogen content H_m of the compound comprises at least one of the hydrogen products.

The anion of the hydrogen product formed by the reaction may be one or more singly negatively charged anions including a halide ion, a hydroxide ion, a hydrogen carbonate ion, a nitrate ion, a double negatively charged anions, a carbonate ion, an oxide, and a sulfate ion. In some examples, the hydrogen product is embedded in a crystalline lattice (*e.g.*, with the use of a getter such as K_2CO_3 located, for example, in the vessel or in an exhaust line). For example, the hydrogen product may be embedded in a salt lattice. In various implementations, the salt lattice may comprise an alkali salt, an alkali halide, an alkali hydroxide, alkaline earth salt, an alkaline earth halide, an alkaline earth hydroxide, or combinations thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate several embodiments of the disclosure and together with the description, serve to explain the principles of the disclosure. In the drawings:

Figure 1 is schematic drawings showing details of the SunCell® thermal power generator comprising a single EM pump injector in an injector reservoir and an inverted pedestal as liquid electrodes in accordance with an embodiment of the present disclosure.

Figures 2-4 are schematic drawings showing details of the SunCell® thermal power generator comprising a single EM pump injector in an injector reservoir and a partially inverted pedestal as liquid electrodes and a tapered reaction cell chamber to suppress metallization of a PV window in accordance with an embodiment of the present disclosure.

Figure 5 is a schematic drawing showing details of the SunCell® thermal power generator comprising a single EM pump injector in an injector reservoir, a partially inverted pedestal as liquid electrodes, an induction ignition system, and a PV window in accordance with an embodiment of the present disclosure.

Figure 6 is a schematic drawing showing details of the SunCell® thermal power generator comprising a cube-shaped reaction cell chamber with a liner and a single EM pump injector in an injector reservoir and an inverted pedestal as liquid electrodes in accordance with an embodiment of the present disclosure.

Figure 7A is a schematic drawing showing details of the SunCell® thermal power generator comprising an hour-glass-shaped reaction cell chamber liner and a single EM pump