SUMMARY

In an aspect, 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.

The power system may comprise a blackbody radiator and a window to output light from the blackbody radiator. Such embodiments 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 plamsa 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 examples, 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 embodiments, the micro-injector injects water into the vessel. In some embodiments, the H_2 molar percentage 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 power system may further comprise a heater to melt a metal (*e.g.*, 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 high-current electrical energy sufficient to cause the reactants to react to form 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 examples, 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 streammakes 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 examples, 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 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 material are tungsten, tantalum, SS 347, and a ceramic. 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.

The molten metal may react with water to form atomic hydrogen *in situ*. In various examples, the molten metal is gallium and the power system further comprises a gallium regeneration system to regenerate gallium from gallium oxide (*e.g.*, gallium oxide produced in the reaction). The gallium regeneration system may comprise a source of at least one of hydrogen gas and atomic hydrogen to reduce gallium oxide to gallium metal. In some examples, hydrogen gas is delivered to the gallium regeneration system from sources external to the power generation system. In some examples, hydrogen gas and/or atomic hydrogen are generated *in situ*. The gallium regeneration system may comprise an ignition system that delivers electrical power to gallium (or gallium/gallium oxide combinations) produced in the reaction. In several examples, such electrical power may electrolyze gallium oxide on the surface of gallium to gallium metal. In some examples, the gallium regeneration system may comprise an electrolyte (*e.g.*, an electrolyte comprising an alkali or alkaline earth halide). In some examples, the gallium regeneration system may comprise a basic pH aqueous electrolysis system, a means to transport gallium oxide into the system, and a means to return the gallium to the vessel (*e.g.*, to the molten metal reservoir). In some examples, the gallium regeneration system comprises a skimmer and a bucket elevator to remove gallium oxide from the surface of gallium. In various examples, the power system may comprise an exhaust line to the vacuum pump to maintain an exhaust gas stream and further comprising an electrostatic precipitation system in the exhaust line to collect gallium oxide particles in the exhaust gas stream.

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 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 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, magnesium fluoride, or combinations thereof. In several examples, the spinning window is coated with a coating that suppresses adherence of at least one of gallium and gallium oxide. The spinning window coating may comprise at least one of diamond like carbon, carbon, boron nitride, and an alkali hydroxide.

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 embodiments, the molten metal may comprise silver. In examples with a magnetohydrodyanamic 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 examples, 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 reaction produces enough energy inorder to initiate the formation of a plasma in the vessel. These reactions may produce a hydrogen product characterized as one or more of:

a) a hydrogen product with a Raman peak at one or more range of 1900 to 2000 cm^{-1} and 5500 to 6100 cm^{-1};

b) a hydrogen product with a plurality of Raman peaks spaced at an integer multiple of 0.23 to 0.25 eV;

c) a hydrogen product with an infrared peak at 1900 to 2000 cm^{-1};

d) a hydrogen product with a plurality of infrared peaks spaced at an integer multiple of 0.23 to 0.25 eV;

e) a hydrogen product with at a plurality of UV fluorescence emission spectral peaks in the range of 200 to 300 nm having a spacing at an integer multiple of 0.23 to 0.3 eV;

f) a hydrogen product with a plurality of electron-beam emission spectral peaks in the range of 200 to 300 nm having a spacing at an integer multiple of 0.2 to 0.3 eV;

g) a hydrogen product with a plurality of Raman spectral peaks in the range of 5000 to 20,000 cm^{-1} having a spacing at an integer multiple of 1000 ± 200 cm^{-1};

h) a hydrogen product with a continuum Raman spectrum in the range of 40 to 8000 cm^{-1};

i) a hydrogen product with a Raman peak in the range of 1500 to 2000 cm^{-1} due to at least one of paramagnetic and nanoparticle shifts;

j) a hydrogen product with a X-ray photoelectron spectroscopy peak at an energy in the range of 490 to 525 eV;

k) a hydrogen product that causes an upfield MAS NMR matrix shift;

l) a hydrogen product that has an upfield MAS NMR or liquid NMR shift of greater than -5 ppm relative to TMS;

m) a hydrogen product comprising macro-aggregates or polymers H_n (n is an integer greater than 3);

n) a hydrogen product comprising macro-aggregates or polymers H_n (n is an integer greater than 3) having a time of flight secondary ion mass spectroscopy (ToF-SIMS) peak of 16.12 to 16.13;

o) a hydrogen product comprising 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;

p) a hydrogen product comprising at least one of H_{16} and H_{24};

q) a hydrogen product comprising an inorganic compound M_xX_y and H_2 wherein M is a cation and X in an anion having at least one of electrospray ionization time of flight secondary ion mass spectroscopy (ESI-ToF) and time of flight secondary ion mass spectroscopy (ToF-SIMS) peaks of $M(M_xX_yH_2)n$ wherein n is an integer;

r) a hydrogen product comprising at least one of $K_2CO_3H_2$ and $KOHH_2$ having at least one of electrospray ionization time of flight secondary ion mass spectroscopy (ESI-ToF) and time of flight secondary ion mass spectroscopy (ToF-SIMS) peaks of $K\left(K_2H_2CO_3\right)_n^+$ and $K\left(KOHH_2\right)_n^+$, respectively;

s) a magnetic hydrogen product comprising 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;

t) a hydrogen product comprising 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 that demonstrates magnetism by magnetic susceptometry;

u) a hydrogen product comprising a metal that is not active in electron paramagnetic resonance (EPR) spectroscopy wherein the EPR spectrum comprises at least one of a g factor of about 2.0046 $\pm$20% and proton splitting such as a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV $\pm$20%;

v) a hydrogen product comprising a hydrogen molecular dimer $[H_2]_2$ wherein the EPR spectrum shows at least an electron-electron dipole splitting energy of about $9.9X10^{-5}$ eV $\pm$20% and a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV $\pm$20%;

w) a hydrogen product comprising a gas having a negative gas chromatography peak with hydrogen or helium carrier;

x) a hydrogen product having a quadrupole moment/e of $\frac{1.70127 a_0^2}{p^2} \pm 10\%$

wherein p is an integer;

y) a protonic hydrogen product comprising a molecular dimer having an end over end rotational energy for the integer J to J + 1 transition in the range of (J+1)44.30 cm^{-1} ±20 cm^{-1} wherein the corresponding rotational energy of the molecular dimer comprising deuterium is ½ that of the dimer comprising protons;

z) a hydrogen product comprising molecular dimers having at least one parameter from the group of (i) a separation distance of hydrogen molecules of 1.028 Å ±10%, (ii) a vibrational energy between hydrogen molecules of 23 cm^{-1} $\pm 10\%$, and (iii) a van der Waals energy between hydrogen molecules of 0.0011 eV $\pm 10\%$;

aa) a hydrogen product comprising a solid having at least one parameter from the group of (i) a separation distance of hydrogen molecules of 1.028 Å ±10%, (ii) a vibrational energy between hydrogen molecules of 23 cm^{-1}±10%, and (iii) a van der Waals energy between hydrogen molecules of 0.019 eV $\pm 10\%$;

bb) a hydrogen product having FTIR and Raman spectral signatures of (i) (J+1)44.30 cm^{-1} ±20 cm^{-1}, (ii) (J+1)22.15 cm^{-1} ±10 cm^{-1} and (iii) 23 cm^{-1} ±10% and/or an X-ray or neutron diffraction pattern showing a hydrogen molecule separation of 1.028 Å ±10% and/or a calorimetric determination of the energy of vaporization of 0.0011 eV ±10% per molecular hydrogen;

cc) a solid hydrogen product having FTIR and Raman spectral signatures of (i) (J+1)44.30 cm^{-1} ± 20 cm^{-1}, (ii) (J+1)22.15 cm^{-1} ± 10 cm^{-1} and (iii) 23 cm^{-1} ±10% and/or an X-ray or neutron diffraction pattern showing a hydrogen molecule separation of 1.028 Å ±10% and/or a calorimetric determination of the energy of vaporization of 0.019 *eV* ±10% per molecular hydrogen.

dd) 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;

ee) 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 some examples, the hydrogen product may be characterized as:

a) a hydrogen product with a continuum Raman spectrum in the range of 40 to 8000 cm^{-1};

b) a hydrogen product with a Raman peak in the range of 1500 to 2000 cm^{-1} due to at least one of paramagnetic and nanoparticle shifts;

c) a hydrogen product with a X-ray photoelectron spectroscopy peak at an energy in the range of 490 to 525 eV;

d) a hydrogen product comprising a metal that is not active in electron paramagnetic resonance (EPR) spectroscopy wherein the EPR spectrum comprises at least one of a g factor of about 2.0046 ±20% and proton splitting such as a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV ±20%;

e) a hydrogen product comprising a hydrogen molecular dimer $[H_2]_2$ wherein the EPR spectrum shows at least an electron-electron dipole splitting energy of about $9.9X10^{-5}$ eV ±20% and a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV ±20%;

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

In certain examples, the reaction produces H_2 which may be characterized as one or more of:

a) having a Fourier transform infrared spectrum (FTIR) comprising at least one of the H_2 rotational energy at 1940 cm^{-1} ±10% and libation bands in the finger print region wherein other high energy features are absent;

b) having a proton magic-angle spinning nuclear magnetic resonance spectrum (^{1}H MAS NMR) comprising an upfield matrix peak;

c) having a thermal gravimetric analysis (TGA) result showing the decomposition of at least one of a metal hydride and a hydrogen polymer in the temperature region of 100 °C to 1000 °C;

d) having an e-beam excitation emission spectrum comprising the H_2 ro-vibrational band in the 260 nm region comprising a plurality of peaks spaced at 0.23 eV to 0.3 eV from each other;

e) having an e-beam excitation emission spectrum comprising the H_2 ro-vibrational band in the 260 nm region comprising a series of peaks spaced at 0.23 eV to 0.3 eV from each other wherein the peaks decrease in intensity at cryo-temperatures in the range of 0 K to 150 K;

f) having a photoluminescence Raman spectrum comprising the second order of the H_2 ro-vibrational band in the 260 nm region comprising a plurality of peaks spaced at 0.23 eV to 0.3 eV from each other;

g) having a photoluminescence Raman spectrum comprising the second order of the H_2 ro-vibrational band comprising a plurality of peaks in the range of 5000 to 20,000 cm^{-1} having a spacing at an integer multiple of 1000 ± 200 cm^{-1};

h) having a Raman spectrum comprising the H_2 rotational peak at one or more of 1940 cm^{-1} ±10% and 5820 cm^{-1} ±10%;

i) having a continuum Raman spectrum in the range of 40 to 8000 cm^{-1};

j) having a Raman peak in the range of 1500 to 2000 cm^{-1} due to at least one of paramagnetic and nanoparticle shifts;

k) having an X-ray photoelectron spectrum (XPS) comprising the total energy of H_2 at 490-500 eV;

l) the hydrogen product interacts $K_2CO_3H(1/4)_2$ and $KOHH_2$ (*e.g.*, in embodiments comprising a getter) 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 $K\left(K_2H_2CO_3\right)_n^+$ and $K\left(KOHH_2\right)_n^+$, respectively;

m) having a quadrupole moment/*e* of $\frac{1.70127a_0^2}{4^2} \pm 10$; and

n) having an end over end rotational energy for the integer J to J + 1 transition in the range of (J+1)44.30 cm^{-1} ±20 cm^{-1} and (J+1)22.15 cm^{-1} ±10 cm^{-1}, respectively;

o) having at least one parameter from the group of (i) a separation distance of H_2 molecules of 1.028 Å ±10%, (ii) a vibrational energy between H_2 molecules of 23 cm^{-1} ±10%, and (iii) a van der Waals energy between H_2 molecules of 0.0011 eV±10%;

p) having FTIR and Raman spectral signatures of (i) (J+1)44.30 cm^{-1} ±20 cm^{-1}, (ii) (J+1)22.15 cm^{-1} ±10 cm^{-1} and (iii) 23 cm^{-1} ±10% and/or an X-ray or neutron diffraction pattern showing a H_2 molecule separation of 1.028 Å ±10% and/or a calorimetric determination of the energy of vaporization of 0.0011 eV ±10% per H_2).

In some examples, the hydrogen product may be formed into a solid H_2 and be characterized as:

a) having at least one parameter from the group of (i) a separation distance of H_2 molecules of 1.028 Å ±10%, (ii) a vibrational energy between H_2 molecules of 23 cm^{-1} ±10%, and (iii) a van der Waals energy between $H_2(1/4)$ molecules of 0.019 eV ±10%;

b) having FTIR and Raman spectral signatures of (i) (J+1)44.30 cm^{-1} ±20 cm^{-1}, (ii) (J+1)22.15 cm^{-1} ±10 cm^{-1} and (iii) 23 cm^{-1} ±10% and/or an X-ray or neutron diffraction pattern showing a hydrogen molecule separation of 1.028 Å ±10% and/or a calorimetric determination of the energy of vaporization of 0.019 eV ±10% per H_2.

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

a) comprise macro-aggregates or polymers H_n (n is an integer greater than 3);

b) comprise macro-aggregates or polymers H_n (n is an integer greater than 3) having a time of flight secondary ion mass spectroscopy (ToF-SIMS) peak of 16.12 to 16.13;

c) 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;

d) comprise at least one of H_{16} and H_{24};

e) 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;

f) 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);

g) 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;

h) comprise a metal that is not active in electron paramagnetic resonance (EPR) spectroscopy wherein the EPR spectrum shows a g factor of about 2.0046 ±20%

and proton splitting such as a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV ±20%;

i) comprise a hydrogen molecular dimer $[H_2]_2$ wherein the EPR spectrum shows at least an electron-electron dipole splitting energy of about $9.9X10^{-5}$ eV ±20% and a proton-electron dipole splitting energy of about 1.6 $X10^{-2}$ eV ±20%,;

j) comprise or releases H_2 gas (*e.g.*, the hydrogen product) having a negative gas chromatography peak with hydrogen or helium carrier;

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 emobodiments 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;

b) MH_n wherein n is 1 or 2, M is an alkaline earth cation and H is the hydrogen product;

c) MHX wherein M is an alkali cation, X is one of a neutral atom such as halogen atom, a molecule, or a singly negatively charged anion such as halogen anion, and H is the hydrogen product;

d) MHX wherein M is an alkaline earth cation, X is a singly negatively charged anion, and H is H is the hydrogen product;

e) MHX wherein M is an alkaline earth cation, X is a double negatively charged anion, and H is the hydrogen product;

f) M_2HX wherein M is an alkali cation, X is a singly negatively charged anion, and H is the hydrogen product;

g) MH_n wherein n is an integer, M is an alkaline cation and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

h) M_2H_n wherein n is an integer, M is an alkaline earth cation and the hydrogen content H_n of the compound comprises at least of the hydrogen products;

i) M_2XH_n wherein n is an integer, M is an alkaline earth cation, X is a singly negatively charged anion, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

j) $M_2X_2H_n$ wherein n is 1 or 2, M is an alkaline earth cation, X is a singly negatively charged anion, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

k) M_2X_3H wherein M is an alkaline earth cation, X is a singly negatively charged anion, and H is the hydrogen product;

l) M_2XH_n wherein n is 1 or 2, M is an alkaline earth cation, X is a double negatively charged anion, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

m) $M_2XX'H$ wherein M is an alkaline earth cation, X is a singly negatively charged anion, X' is a double negatively charged anion, and H is the hydrogen product;

n) $MM'H_n$ wherein n is an integer from 1 to 3, M is an alkaline earth cation, M' is an alkali metal cation and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

o) $MM'XH_n$ wherein n is 1 or 2, M is an alkaline earth cation, M' is an alkali metal cation, X is a singly negatively charged anion and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

p) MM'XH wherein M is an alkaline earth cation, M' is an alkali metal cation, X is a double negatively charged anion and H is the hydrogen products;

q) MM'XX'H wherein M is an alkaline earth cation, M' is an alkali metal cation, X and X' are singly negatively charged anion and H is the hydrogen product;

r) $MXX'H_n$ wherein n is an integer from 1 to 5, M is an alkali or alkaline earth cation, X is a singly or double negatively charged anion, X' is a metal or metalloid, a transition element, an inner transition element, or a rare earth element, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

s) MH_n wherein n is an integer, M is a cation such as a transition element, an inner transition element, or a rare earth element, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

t) MXH_n wherein n is an integer, M is an cation such as an alkali cation, alkaline earth cation, X is another cation such as a transition element, inner transition

element, or a rare earth element cation, and the hydrogen content H_n of the compound comprises at least one of the hydrogen products;

u) $\left(MH_mMCO_3\right)_n$ wherein M is an alkali cation or other +1 cation, m and n are each an integer, and the hydrogen content H_m of the compound comprises at least one of the hydrogen products;

v) $\left(MH_mMNO_3\right)_n^+ \; nX^-$ wherein M is an alkali cation or other +1 cation, m and n are each an integer, X is a singly negatively charged anion, and the hydrogen content H_m of the compound comprises at least one of the hydrogen products;

w) $\left(MHMNO_3\right)_n$ wherein M is an alkali cation or other +1 cation, n is an integer and the hydrogen content H of the compound comprises at least one of the hydrogen products;

x) $\left(MHMOH\right)_n$ wherein M is an alkali cation or other +1 cation, n is an integer, and the hydrogen content H of the compound comprises at least one of the hydrogen products;

y) $\left(MH_mM'X\right)_n$ wherein m and n are each an integer, M and M' are each an alkali or alkaline earth cation, X is a singly or double negatively charged anion, 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 examples, 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.

In another aspect, electrode systems are also provided comprising:

a) a first electrode and a second electrode;

b) a stream of molten metal (*e.g.*, molten silver, molten gallium) in electrical contact with said first and second electrodes;

c) a circulation system comprising a pump to draw said molten metal from a reservoir and convey it through a conduit (*e.g.*, a tube) to produce said stream of molten metal exiting said conduit;

d) a source of electrical power configured to provide an electrical potential difference between said first and second electrodes;

wherein said stream of molten metal is in simultaneous contact with said first and second electrodes to create an electrical current between said electrodes. In some examples, the electrical power is sufficient to create a current in excess of 100 A.

In another aspect, electrical circuits are also provided which may comprise:

a) a heating means for producing molten metal;

b) a pumping means for conveying said molten metal from a reservoir through a conduit to produce a stream of said molten metal exiting said conduit;

c) a first electrode and a second electrode in electrical communication with a power supply means for creating an electrical potential difference across said first and second electrode;

wherein said stream of molten metal is in simultaneous contact with said first and second electrodes to create an electrical circuit between said first and second electrodes. For example, in an electrical circuit comprising a first and second electrode, the improvement may comprise passing a stream of molten metal across said electrodes to permit a current to flow there between.

Additionally, in another aspect, systems for producing a plasma (which may be used in the power generation systems described herein) are provided. These systems may comprise:

a) a molten metal injector system configured to produce a stream of molten metal from a metal reservoir;

b) an electrode system for inducing a current to flow through said stream of molten metal;

c) at least one of a (i) water injection system configured to bring a metered volume of water in contact with said molten metal, wherein a portion of said water and a portion of said molten metal react to form an oxide of said metal and hydrogen gas, (ii) a mixture of excess hydrogen gas an oxygen gas, and (iii) a mixture of excess hydrogen gas and water vapor, and

d) a power supply configured to supply said current;

wherein said plasma is produced when current is supplied through said metal stream. In some examples, the system may further comprise:

a pumping system configured to transfer metal collected after the production of said plasma to said metal reservoir. In some examples, the system may comprise:

a metal regeneration system configured to collect said metal oxide and convert said metal oxide to said metal; wherein said metal regeneration system comprises an anode, a cathode, electrolyte; wherein an electrical bias is supplied between said anode and cathode to convert said metal oxide to said metal. In certain examples, the system may comprise:

a) a pumping system configured to transfer metal collected after the production of said plasma to said metal reservoir; and

b) a metal regeneration system configured to collect said metal oxide and convert said metal oxide to said metal; wherein said metal regeneration system comprises an anode, a cathode, electrolyte; wherein an electrical bias is supplied between said anode and cathode to convert said metal oxide to said metal;

wherein metal regenerated in said metal regeneration system is transferred to said pumping system. In certain examples, the metal is gallium, silver, or combinations thereof. In some examples, the electrolyte is an alkali hydroxide (*e.g.*, sodium hydroxide, potassium hydroxide).

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 a schematic drawing of magnetohydrodynamic (MHD) converter components of a cathode, anode, insulator, and bus bar feed-through flange in accordance with an embodiment of the present disclosure.

FIGURES 2-3 are schematic drawings of a SunCell® power generator comprising dual EM pump injectors as liquid electrodes showing tilted reservoirs and a magnetohydrodynamic (MHD) converter comprising a pair of MHD return EM pumps in accordance with an embodiment of the present disclosure.

FIGURE 4 is schematic drawings of a single-stage induction injection EM pump in accordance with an embodiment of the present disclosure.

FIGURE 5 is schematic drawings of magnetohydrodynamic (MHD) SunCell® power generators comprising dual EM pump injectors as liquid electrodes showing tilted reservoirs, a spherical reaction cell chamber, a straight magnetohydrodynamic (MHD) channel, gas addition housing, and single-stage induction EM pumps for injection and either single-stage