CLAIMS

1. A self-sustainable solid oxide fuel cell (SOFC) system for powering a gas well comprising:

a first SOFC comprising a first cathode, a first anode, and a first solid electrolyte disposed between the first cathode and the first anode;

a second SOFC comprising a second cathode, a second anode, and a second solid electrolyte disposed between the second cathode and the second anode fluidly connected to a first products stream from the first SOFC;

SO_2 removal equipment in fluid communication with the first SOFC to remove SO_2;

a combustion circuit comprising a combustor and a circulating heat carrier fluidly connected to a second products stream from the second SOFC; and

one or more external electric circuits connected to the first SOFC and the second SOFC, wherein

the first anode comprises a first oxidation region configured to produce SO_2 and electrons from H_2S in a natural gas feed stream;

the second anode comprises a second oxidation region configured to electrochemically oxidize CH_4 in the first products stream to produce syngas and electrons and electrochemically oxidize H_2 to produce H_2O and electrons;

the circulating heat carrier is in thermal connection with the combustor, the first SOFC, and the second SOFC such that heat generated in the combustor from combustion of at least the second products stream is distributed to the first SOFC to maintain the first SOFC at a first operating temperature and distributed to the second SOFC to maintain the second SOFC at a second operating temperature, the first and second operating temperatures in excess of 700 °C; and

the external electric circuits are configured to generate power from the electrons produced in both the first SOFC and the second SOFC.

2. The system of claim 1 wherein the first anode and the second anode are solid metal anodes.

3. The system of claim 1 wherein the SO_2 removal equipment is disposed between the first SOFC and the second SOFC.

4. The system of claim 1 wherein the first anode is a molten metal anode.

5. The system of claim 4 wherein the self-sustainable SOFC system further comprises a molten metal conduit configured to circulate the molten metal of the first anode.

6. The system of claim 5 wherein:

the self-sustainable SOFC system further comprises a sulfation region configured to produce metal sulfides from metals in the first anode; and

the metal sulfides are electrochemical oxidized upon contact with the first solid electrolyte to produce SO_2 and electricity.

7. The system of claim 5 wherein:

the self-sustainable SOFC system further comprises a sulfation region configured to produce metal sulfides from metals in the first anode; and

the SO_2 removal equipment is disposed in the molten metal conduit between the first solid electrolyte and the sulfation region in the flow of the first anode and comprises a separating column or membrane.

8. The system of any of claims 1 through 7 wherein the circulating heat carrier maintains the first operating temperature and the second operating temperature at 700 °C to 900 °C.

9. The system of any of claims 1 through 7 wherein the first solid electrolyte, the second solid electrolyte, or both comprises zirconia-based electrolytes or ceria-based electrolytes.

10. The system of any of claims 1 through 7 wherein the first cathode, the second cathode, or both is selected from the group consisting of lanthanum strontium manganite (LSM), yttria stabilized ZrO_2/lanthanum strontium manganite (YSZ-LSM), lanthanum strontium cobalt ferrite (LSCF), and combinations thereof.

11. The system of any of claims 1 through 7 wherein the self-sustainable solid oxide fuel cell system further comprises an external fuel supply to the combustion circuit.

12. A method for generating electricity from sour natural gas, the method comprising:

providing a solid oxide fuel cell (SOFC) system comprising

a first SOFC comprising a first cathode, a first anode, and a first solid electrolyte disposed between the first cathode and the first anode;

a second SOFC comprising a second cathode, a second anode, and a second solid electrolyte disposed between the second cathode and the second anode fluidly connected to a first products stream from the first SOFC;

SO_2 removal equipment in fluid communication with the first SOFC to remove SO_2;

a combustion circuit comprising a combustor and a circulating heat carrier fluidly connected to a second products stream from the second SOFC; and

one or more external electric circuits connected to the first SOFC and the second SOFC;

feeding the sour natural gas to the first SOFC;

producing SO_2 and electrons from H_2S in the sour natural gas at a first oxidation region of the first anode;

removing SO_2 from the system with the SO_2 removal equipment;

feeding the first products stream from the first SOFC with the SO_2 removed to the second SOFC;

electrochemically oxidizing CH_4 from the first products stream from the first SOFC in a second oxidation region of the second anode to produce syngas and electrons;

feeding the second products stream from the second SOFC to the combustion circuit and burning the syngas in the combustor to generate heat;

distributing the heat generated in the combustor to the first SOFC and the second SOFC via the circulating heat carrier;

feeding a combustion product stream from the combustor to the second SOFC; and

generating electricity with the one or more external electric circuits by collecting electrons generated in the first SOFC and the second SOFC.

13. The method of claim 12 wherein the method further comprises electrochemically oxidizing H_2 from the first products stream from the first SOFC in the second oxidation region of the second anode to produce H_2O and electrons.

14. The method of any of claims 12 through 13 wherein:

the first anode is a molten metal anode; and

producing SO_2 and electrons from H_2S in the sour natural gas comprises contacting the first anode with the H_2S from the sour natural gas to produce metal sulfides and oxidizing the metal sulfides in the first oxidation region to produce SO_2.

15. The method of any of claims 12 through 13 wherein:

the first anode is a solid metal anode; and

producing SO_2 and electrons from H_2S in the sour natural gas comprises directly oxidizing the H_2S from the sour natural gas to SO_2 in the first oxidation region.