Solid Oxide Electrochemical Device For Efficient Energy Production And Clean-Up Of Wet Biomass.

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This paper will describe the concept and preliminary results of an intermediate temperature micro-tubular solid oxide fuel cell (SOFC) encased in a super critical water (SCW) reactor for use in a stand-alone micro-sanitation and water repurification system (SeCoM) for point-of-use detoxification of aqueous waste under real-world conditions. The SeCoM is a non-microbial system that mineralizes a variety of biomass reactants via a sequence of ceramic SOFC microchannel reactor modules.

The basic concept of SCW is that water enters supercritical state when the temperature is greater than or equal to 374^{0}C and the pressure is greater than or equal to 22.1MPa. SCW is neither a liquid nor a gas but retains some properties of each. It has a high miscibility with many gases including O_2, N_2, CO_2, CH_4 as well as biomass and other organics. In effect, the SOEC comprises an electrolyte sandwiched between an anode and a cathode. The cell is fabricated by making a plastic mass of the ceramic cathode, and extruding it into a thin porous (to allow oxygen to diffuse through) closed-end tube, using standard ceramic extrusion technology. The tube is then fired at high temperature to ensure it has sufficient strength and durability to be used in the reactor. The electrolyte and anode are then coated onto the porous cathode support tube, using dip coating techniques. The whole is then fired again at high temperature to ensure that the layers are well adhered, and oxygen ions and electrons can freely move. The electrolyte is a thin dense ceramic that conducts oxygen ions (O^{2-}) but is impermeable to molecular oxygen (O_2); it is also a poor conductor of free electrons. The oxidation reaction occurs at the anode (on the outside of the tube), which is exposed to the SCW, containing the oxidant (for example waste). At the cathode, the electrochemical reduction of O_2 (from the air pumped down the center of the tube) to O^{2-} ions occurs, which then transport through the electrolyte (at ≥450°C) via an ionic hopping mechanism, driven by the pO_2 gradient across the membrane. Electrochemical oxidation of the fuel (CO and H_2, derived by ‘reforming’ of feedstock) occurs at the ‘triple phase boundary’ on the surface of the anode, where fuel, SCW, O^{2-} ions, and electron collector co-locate. Electrons are captured and routed back to the cathode via an external circuit.

The paper will describe the fabrication of the micro-tubes and how they behave in the SCW reactor. Preliminary results for the SOEC will be discussed using a variety of fuels and thermal and electrochemical conditions. The initial results show that the concept is extremely promising, and that the tubes can be easily fabricated with sufficient mechanical integrity to survive the conditions of the SCW. Further work will study the use of the system under bio-mass conditions necessary for clean-up of waste with an output of electricity and clean by-products.

Figure 1 shows a photograph of the reactor used in this work, where the SOFC tube is placed inside the reactor with the anode on the outside of the tube, and air passed down the center. The reactor uses liquid fuels, and has been tested on a number of different logistical and bio-based systems, which will be discussed.

Fig. 1 Photograph of the SCW reactor