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THE EFFECT OF VARYING HIERARCHICAL POROSITY ON THE MASS TRANSPORT RESISTANCE OF TUBULAR SOFC/SOEC TECHNOLOGY DESIGNED FOR ADVANCED REGENERATION SYSTEMS

Abstract

Fuel cell technology is an important element within current designs to enable human beings onboard deep space missions and during colonization of nearby planets such as Mars. Future fuel cells will be expected to operate directly and reversibly with hydrocarbon based fuels such as LOX-methane reserves and not just hydrogen and oxygen gasses like previously demonstrated in previous space missions. Solid oxide fuel cell/ solid oxide electrolysis cell (SOFC/SOEC) technology offers great potential for use as a regenerative fuel cell with LOX-methane due to the chemical compatibility and fast oxidation kinetics at higher operating temperatures with syn or directly fed methane gasses. Much effort has been spent towards testing materials to improve the activation polarization as well as redox stability when switched between SOFC and SOEC modes. Unfortunately, much of the effort revealed in literature has limited utility and provides minimal information for scaling towards a system level design. SOFC/SOEC systems are complicated electrochemical systems and therefore research and testing should at a minimum provide some clarity and quantification as to how the technological solution can improve the current state of ISRU capabilities and reliability. The research described herein is based upon a tubular SOFC design that can easily be scaled from single testing cells to operating stacks with appreciable power output. The specific purpose of this research is to quantify meaningful improvements made to the mass transport and concentration polarizations by examining the effect of varying porosity and active area of the supporting structure of an anode-supported tubular SOFC/SOEC. The tubular supports were prepared via a technique referred to as the freeze cast process and is known for forming hierarchical pore structure that is preferentially aligned to the fuel path direction. The total porosity within the support structure was controlled by changing the total water to solids ratio within the casting slip prior to the freeze cast process. Complete SOFC and SOEC structures of standard and exotic material sets were processed and evaluated including electrical impedance spectroscopy and voltage-current plots under controlled voltage/current settings. Post mortem examination of tubes were completed to determine the total porosity of the anode support substrate, thickness of electrochemical active layers, and B.E.T. surface area of the porous support structures. The results reveal that the mass transport resistance is minimized as the porosity is increased up to a maximum at which point the flexure strength of the porous supporting substrate is jeopardized.