IAF/IAA SPACE LIFE SCIENCES SYMPOSIUM (A1)
Life Support, habitats and EVA Systems (7)

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MODELING ELECTROLYTIC O2 RECOVERY FROM METABOLIC CO2 FOR ADVANCED CLOSED LOOP LIFE SUPPORT SYSTEMS IN EXTRATERRESTRIAL HUMAN MISSIONS

Abstract

The state-of-the-art oxygen (O2) recovery system for the International Space Station (ISS) is a complex, heavy, and power consuming system that recovers approximately 50% of O2 from metabolic carbon dioxide (CO2). Future extraterrestrial human missions, including mission to Mars, will necessitate a sustainable and highly-efficient metabolic O2 recovery system capable of yielding a minimum of 75% O2 recovery. A Macrofluidic Electrochemical Reactor (MFECR) technology development effort is currently underway at NASA Marshall Space Flight Center (MSFC) to significantly increase current metabolic O2 recovery efficiency, expand mission sustainability, and reduce complexity of the system. The novel design combines CO2 conversion to O2 and water electrolysis, currently conducted in two separate units, into a single compact unit that runs at standard conditions, is capable of recovering O2 and yielding ethylene (C2H4) as byproducts, and has a theoretical maximum metabolic CO2 conversion of 73% while consuming less metabolic water. This paper presents a comprehensive multi-physic 3D model developed at MSFC on CO2 conversion to O2 and C2H4 at standard conditions via MFECR. The 3D spatial domain of the model is a replica of the actual MFECR's 3D drawing generated for the MFECR fabrication and operated to recover O2 from CO2 yielding C2H4 as byproduct. Electrochemical (EC) physics that includes EC multicomponent reaction mechanisms, mass transport, and electrical current density distributions is coupled in the model with all the other physics involved in the MFECR's process, such as two-phase flow, free and porous fluid regimes, multicomponent mass transfer, heat transfer, and electrical current along with Joule-heating effect. The EC reaction domains within the MFECR consists of two porous gas diffusion electrodes (GDE) and an electrolyte serpentine channel sandwiched in the middle. The CO2 feeds the cathode serpentine channel and part of the O2 product is fed back to the anode serpentine chamber. An alkaline solution feeds the electrolyte serpentine chamber wetting the GDEs of both, the anode and

cathode allowing the OH^- ionic transport between them. The EC reactions in the cathode's GDE yield C_2H_4 from CO_2 and hydrogen (H_2) from water while the EC reaction in the anode's GDE yields O_2. The authors present in this paper the validation of the model using experimental data and the utilization of the validated model in building a reliable simulator that will not only assist the authors on the MFECR design but also the optimization of its operation in the ISS and future extraterrestrial human missions.