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SRR&PTMSS Abstract, 2018

Production of methane and oxygen on Mars using proton-conducting ceramics

In this NASA-funded program, we are developing novel ceramic electrochemical devices to convert carbon dioxide and water vapor into oxygen and methane fuel in a single step. If successful, the technology could be used to fuel a Mars ascent vehicle and sustain human life on Mars.

Human exploration of Mars can be made feasible and sustainable with In-Situ Resource Utilization (ISRU). ISRU refers to the harnessing and utilizing of resources found or manufactured on extraterrestrial sites to support or enhance space missions. Abundant Martian resources include carbon dioxide, which makes up 95% of Mars atmosphere, and water in Martian regolith. Proton-conducting ceramics have unique properties that could be harnessed as an innovative ISRU technology to make use of these in-situ resources to produce oxygen and methane directly on Mars. The process is shown in Figure 1. At the steam electrode, water vapor is electrolyzed to form protons and molecular oxygen. As the oxygen is exhausted, the protons are driven across the proton-conducting ceramic membrane to the methane electrode. At the methane electrode, protons react with carbon dioxide to make methane. The process effectively combines water electrolysis and carbon dioxide hydrogenation, also known as the Sabatier reaction, within a single “Sabatier-electrolyzer”.

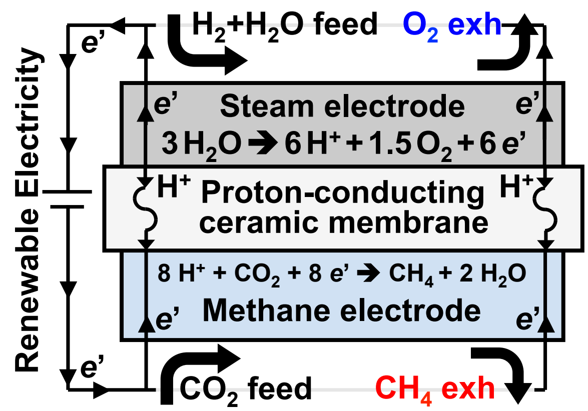

Figure 1: Illustration of the Sabatier electrolyzer featuring proton-conducting ceramics for producing methane fuel and oxygen from carbon dioxide and water.

We have built and are now beginning our first experiments of a small-scale Sabatier-electrolysis reactor. The experiment utilizes state-of-the-art proton-conducting ceramics fabricated at the Colorado School of Mines to characterize Sabatier and electrolysis performance over a wide range of operating conditions. Development of the reactor involves integration of Sabatier catalysts to maximize methane formation. In addition, we are developing a computational model to explore fundamental device operation, validate experimental data, and develop scaling designs to meet NASA critical performance Mars ISRU specifications. This work is supported by a NASA Space Technology Research Fellowship.