Paper ID: 84293
student

22nd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (D3)
Interactive Presentations - 22nd IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT (IP)

Author: Ms. Lanie McKinney
Massachusetts Institute of Technology (MIT), United States, laniemck@mit.edu

Prof. Carmen Guerra-Garcia
Massachusetts Institute of Technology (MIT), United States, guerrac@mit.edu

PLASMA REACTORS FOR CHEMICAL CONVERSION AND RESOURCE GENERATION BEYOND LOW-EARTH ORBIT

Abstract

As humanity gears up for its return to the moon after more than half a century, collaborative efforts between NASA, Artemis Accords Partners, and private industry are underway to establish the necessary infrastructure and technologies for lunar habitation and eventual Mars exploration. However, the traditional ISS resupply and waste management model is impractical and economically infeasible for prolonged missions to the Moon and Mars. Advanced chemical conversion technologies are needed to generate vital consumable products from local planetary resources (ISRU) and recycled gasses and waste within semi-closed loop life-support systems.

Low-temperature plasma reactors are emerging power-to-gas technologies with the potential to facilitate various chemical synthesis processes with hardware commonality and redundancy. In plasma-based systems, electrical power is used to ionize a feedstock gas, creating a highly reactive environment that leverages electron excitation chemistry to break stable molecular bonds and form value-added products. Unlike thermal chemical processes, plasma reactors operate at non-equilibrium conditions, allowing for lower-temperature operation and instantaneous start-up, making them adaptable to intermittent power availability. Moreover, their scalability permits deployment in both portable astronaut systems and large-scale industrial setups for colonies.

One promising application of plasmas is for CO2 conversion. Carbon dioxide comprises 96% of the Martian atmosphere and is a byproduct of human respiration, which typically must be scrubbed and vented from space habitats. A plasma source integrated with membrane separation technology can generate a pure stream of oxygen for life support and rocket propellant. CO2 splitting may also be beneficial as a precursor to manufacture carbon-based products and fuels in situ, like methane, methanol, and polyethylene. Plasma-assisted CO2 conversion is a simpler case to study without the concern of selectivity and is the first step toward complex chemical synthesis. This work presents preliminary experimental results from a plasma reactor for CO2 conversion and casts a vision for the potential of plasma technologies in resource production to enable the next generation of human spaceflight activities.