

PhD Project: In-Situ Production of Oxygen on Mars Using Inductively Coupled Plasmas

The space group (UNSW Canberra Space) within the School of Engineering and Technology at the University of New South Wales (UNSW) Canberra has an open PhD position in the fields of plasma physics and gas conversion for space applications.

Context

The exploration and colonization of Mars presents numerous challenges, particularly with regards to ensuring a sustainable supply of essential resources such as oxygen. With the Martian atmosphere composed of approximately 95% carbon dioxide (CO₂), one promising solution is the in-situ production of oxygen. While several previous works have proposed the use of DC or Radio-Frequency (RF) Capacitively Coupled Plasmas (CCPs) to generate oxygen from CO₂, challenges with output capacity, energy efficiency, and operating lifetime remains. This project aims to explore the use of Inductively Coupled Plasmas (ICPs; sometimes also referred to as inductive plasma torches) as an alternative electrodeless method to more efficiently convert Martian CO₂ into oxygen. Such oxygen can then be utilized for both life support and as a propellant for chemical or electrothermal propulsion systems.

Inductive plasma torches offer a highly controlled and energy-efficient means of breaking down CO₂ molecules through ionization and dissociation. By applying a time-varying current to an RF coil, electric fields are generated that can be used to sustain a high-density plasma. CO₂ can then be fragmented through various collisional processes into oxygen and carbon monoxide (CO), with oxygen serving as a vital resource for astronauts, and both oxygen and CO potentially having value as propellants for chemical propulsion systems. This would represent a critical step in advancing In-Situ Resource Utilization (ISRU) technologies, enabling future missions to Mars to be less reliant on Earth-based supply chains.

This project will combine global modelling and experimental testing of inductive plasma torches operated with CO₂. Detailed plasma kinetics will explore the characteristics of CO₂ plasmas, while experimental measurements will validate the model and help to optimize system efficiency under Martian conditions. By leveraging inductive plasma torches for oxygen production, this research aims to contribute to the feasibility of a long-term human presence on Mars, supporting both human survival and future space exploration missions.

Project Scope

This project aims to numerically and experimentally study low-pressure CO₂ plasmas produced by an inductive plasma torch. In particular, it involves 3 main objectives:

- A. Development of a detailed 0D model to study non-equilibrium CO₂ plasma kinetics in an inductive plasma torch. This model will include various collisional and diffusive processes and may also include radiative processes enabling the generation of synthetic emission spectra (i.e. a “collisional-radiative” model). Ideally the model will also account for non-Maxwellian electron energy distribution functions.
- B. Perform an experimental characterization of CO₂ plasmas using existing inductive plasma torch experiments. Diagnostics will include electrical circuit probes, pressure probes, water calorimetry, optical emission spectroscopy, and optical absorption spectroscopy. Electrostatic probes, such as RF compensated Langmuir probes, may also be used. Experiments will be compared with the 0D model developed in Objective A and will study the effect of novel vortex gas injections schemes recently proposed.

- C. Compare the experimental and model results with existing (or additional) experimental data obtained from RF CCP and DC plasma systems hosted at Ecole Polytechnique in France. An important aim will be to assess the oxygen production capability and energy efficiency of the inductive plasma torch compared with these other systems.

Project Partners

This project will be performed in collaboration with the Research School of Physics at the Australian National University (ANU), the Laboratoire de Physique des Plasmas at Ecole Polytechnique in France, and the Instituto de Plasmas e Fusao at Instituto Superior Technico in Portugal. There is potential for the student to visit France and Portugal during their PhD to interact with project collaborators.

Candidate Profile

The ideal candidate will have a background in physics and/or engineering with strong mathematical, programming, and communication skills.

Contact

Express your interest in this project by emailing Dr Trevor Lafleur at t.lafleur@unsw.edu.au. Include a copy of your CV and provide a brief motivation that highlights your research experience.

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