Insights into CO_2 conversion with plasma-electrolysis synergy

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In-situ resource utilization (ISRU) is vital for the human colonization of Mars, in order to be self-sufficient for food and energy production [1]. The Martian atmosphere consists of CO_2 (95.9%), Ar (1.9%) and N_2 (1.9%). This CO_2 abundance can provide a feedstock for direct conversion into O_2 and CO, which can be used for life support and energy conversion respectively.

Amongst the CO_2 conversion and oxygen production technologies, the most promising is the combination of non-thermal plasmas and solid oxide electrolyte cell (SOEC) with an oxygen separation membrane. Although the CO_2 splitting can be performed at the SOEC surface, it requires high temperatures (typically 700-900°C) to break the stable carbon-oxygen double bonds electrochemically. The non-thermal plasma provides a highly-chemical-activated environment favorable for CO_2 dissociation, while the SOEC can separate the O_2 from the plasma environment, limiting the backward reaction of CO combing with O_2 to form CO_2. The plasma-SOEC synergy effects have been reported [2,3], but no detailed investigations of the plasma-SOEC performance enhancement have been conducted.

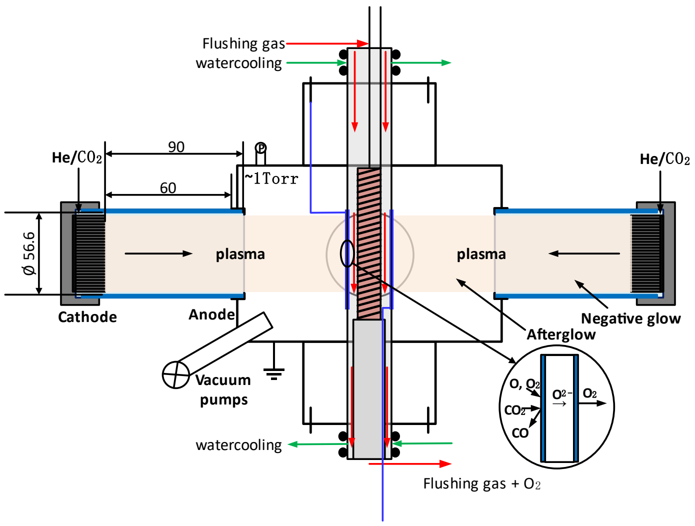

Fig. 1: The scheme of the SOEC integration into the BABE reactor.

To elucidate the kinetics behind the plasma-SOEC synergy, we investigate the plasma-SOEC interactions in the BAri Brush Electrode (BABE) reactor [4] with four DC glow discharges and the afterglow region between their ring anodes. The tubular SOEC consisting of yttria-stabilized zirconia (YSZ) electrolyte and lanthanum strontium manganite (LSM) electrodes is situated in the afterglow region. The scheme of the setup is shown in fig. 1. We investigate several essential factors, including plasma parameters, SOEC working temperatures and bias, and their effects on the catalytic process, aiming to reach a higher oxygen permeation whilst limiting SOEC working temperature. The CO_2 conversion is studied for He(80%)-CO_2(20%) gas mixture with the pressure of 1 Torr. The plasma conditions are investigated in the discharge region by means of optical emission spectroscopy and in the afterglow region using a Langmuir probe. The dissociation products are determined by mass-spectrometry.

The oxygen pumping experiments demonstrate that the glow discharge can enhance the oxygen transport at the low SOEC working temperatures (350-650℃). At 298W discharge power and 10 sccm feed gas flow, the oxygen permeation can be enhanced from ~0.07mln/min to ~0.6mln/min. Simultaneously, the oxygen separation enhances the CO_2 conversion from 87.1% to 89.7%. The OES shows that the oxygen pumping out of the afterglow region also reduces the intensities of the atomic oxygen lines in the discharge region. In our conditions, the plasma-induced enhancement of the oxygen permeation grows with increasing plasma power, reaching saturation at ~300W. The results are compared with the experiments with He-O_2 and pure He experiments [5].

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