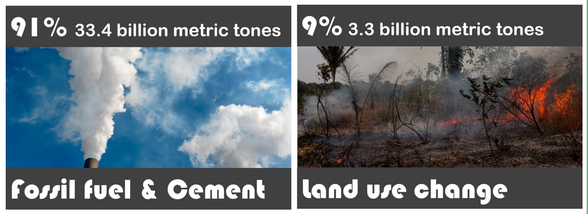
Advanced Electrochemical System for Energy Storage Through CO_2 Conversion

Bin Hua[1], Wan-Ying Pan[2], Zhe-Hui Jin[2], Meng Li[1], Jing-Li Luo[1]

BACKGROUND

Where does humanity's CO_2 come from?



Where does humanity's CO_2 go?

50% of CO_2 goes to the Atmosphere
26% of CO_2 goes to the Land
24% of CO_2 goes to the Ocean

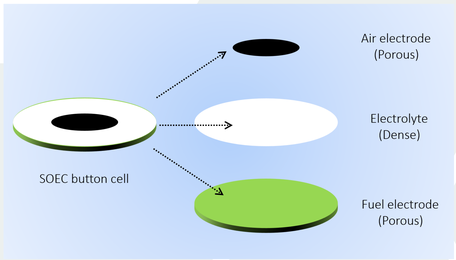
Carbon dioxide utilization: an urgent and important carbon-neutral energy cycle

SHORT-TERM OBJECTIVES

Current goals

- Fabricate solid oxide electrolyzer with highly conductive oxide as the thin electrolyte in order to decrease the operating temperature of a solid oxide electrolyzer (SOE).
- Find the optimal fabrication parameters, such as sintering procedure, density and thickness of the thin electrolyte layer.
- Use the home-made SOE to efficiently convert CO_2 to CO at 650 degree C.

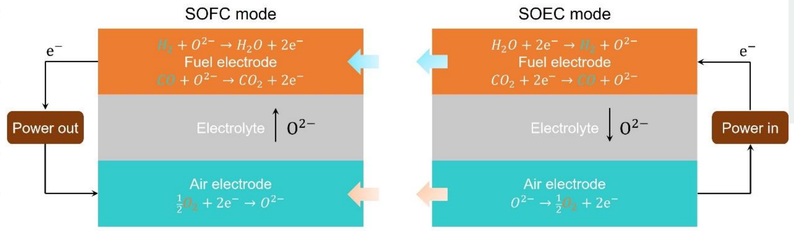
Sandwich-structural SOE



PROJECT OVERVIEW

Working principles and cell components

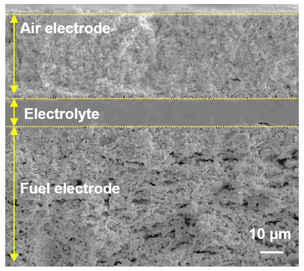
Solid oxide fuel cells (SOFCs) are considered one of the cleanest technologies to generate electricity in light of their low or zero greenhouse emissions. The reverse operation of SOFCs (solid oxide electrolyzer cells, SOECs) also offers the most efficient route for energy storage, in comparison with the conventional electrolyzers.



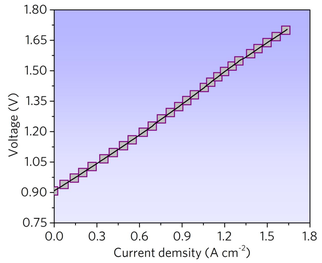
$$H_2 + CO + O_2 \leftrightarrow H_2O + CO_2 + electricity\ (\Delta G) + heat\ (T\Delta S)$$

Schematically showing the working principle and components of a typical reversible solid oxide cell

Microstructure and electrochemical behavior



Cross-sectional microstructures of an SOEC

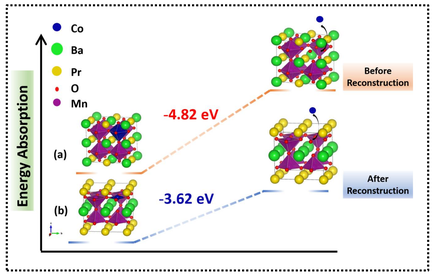


Electrochemical performance of a conventional YSZ based SOEC

- The picture shows a convectional high temperature SOEC, which is composed of porous fuel electrode, dense electrolyte, and porous air electrode.
- As the voltage/current density curve shown, such an SOEC achieves high performance in CO_2-CO mixture at 800 degree C.

Computational simulation

- Exsolving metallic nanoparticles is an effective way to enhance the catalytic activity of SOEC electrodes.
- Via the computational simulation, we shed light on the influence of crystal structure on the exsolution behavior.



Comparison of the energy barriers for exsolving a Co atom from two types of perovskite

THEME OVERVIEW

Carbon Capture, Utilization & Storage

Hydrocarbons will continue to serve as an essential energy source while the world transitions to a lower-carbon energy economy, but can we prevent the use of those fuels from contributing to the accumulation of CO_2 in the atmosphere? Existing technologies can capture carbon, but these methods can be costly and energy-intensive. Extracting energy without burning fuels, improving CO_2 capture efficiencies if they are burned, and finding effective ways to store or reuse captured carbon may be essential to ensuring it does not enter the atmosphere.

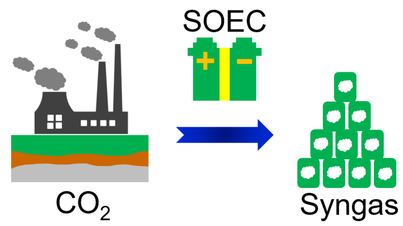
EXPECTED OUTCOMES

Engineering

- The main outcome of this research is a stable, high performing solid oxide electrolysis device that demonstrates tunable syngas production from CO_2 and steam at the cathode, and a pure O_2 stream at the anode, while also serving to store renewable and excess grid electricity.

Science

- Cell optimization and advanced theory and advanced surface science experiments, will allow leading edge insights to be obtained, thus helping with knowledgeable modification of catalyst composition and other fundamental factors.



EXTERNAL PARTNERS

Viola Birss
Department of Chemistry, University of Calgary.

Jian Chen
National Institute for Nanotechnology, National Research Council Canada.

Jian Li
Department of materials science, Huazhong University of Science and Technology.

[1]Department of Chemical and Materials Engineering, University of Alberta, Edmonton, Alberta T6G 1H9, Canada.
[2]Department of Civil & Environmental Engineering, University of Alberta, Edmonton, Alberta T6G 1H9, Canada.

UNIVERSITY OF ALBERTA
FUTURE ENERGY SYSTEMS

CANADA FIRST RESEARCH EXCELLENCE FUND

This research has been undertaken thanks in part to funding from the Canada First Research Excellence Fund.