The Effect of Carbon Supported and Unsupported IrOx on Reversal Tolerance and Anode Durability

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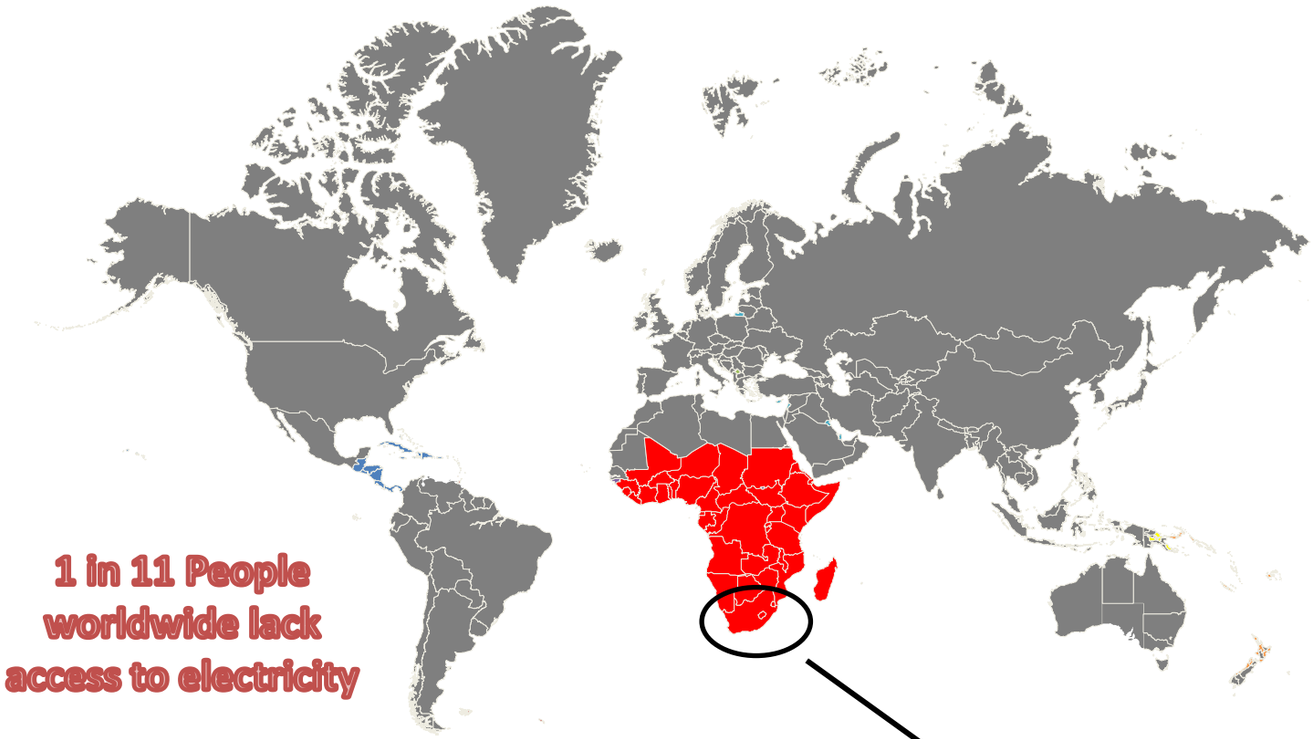
2nd Southern African Hydrogen and Fuel Cell Conference

7th-8th April 2025

Global Energy Crisis



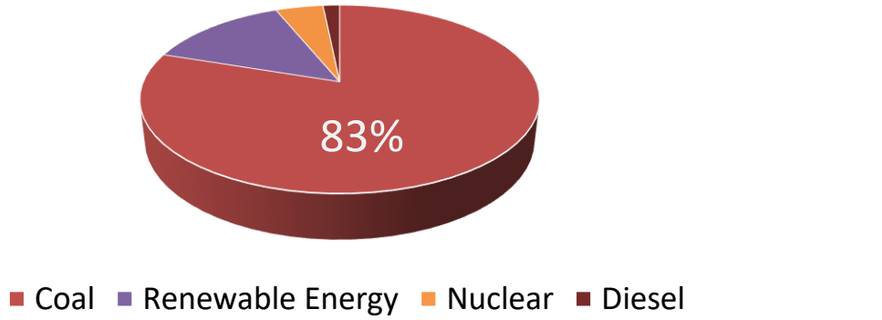
1 in 11 People worldwide lack access to electricity

Sub-Saharan Africa accounts for 80% of the world population lacking access to electricity

Energy Demand

- ❑ Population Growth
- ❑ Economic growth
- ❑ Industrialization
- ❑ Technological Advances

South Africa's Energy Sources 2023

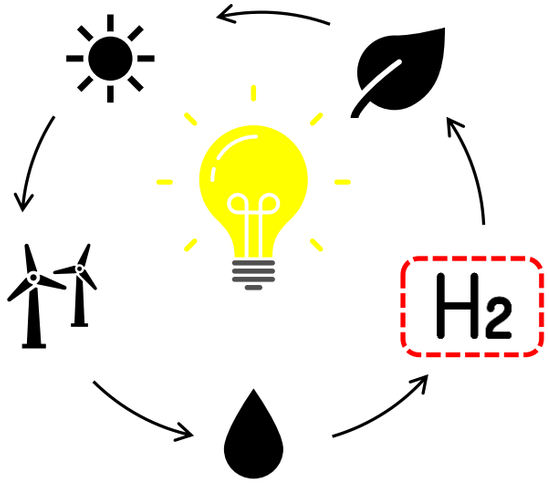


SA Energy Sector Report, Manyane T, 2023

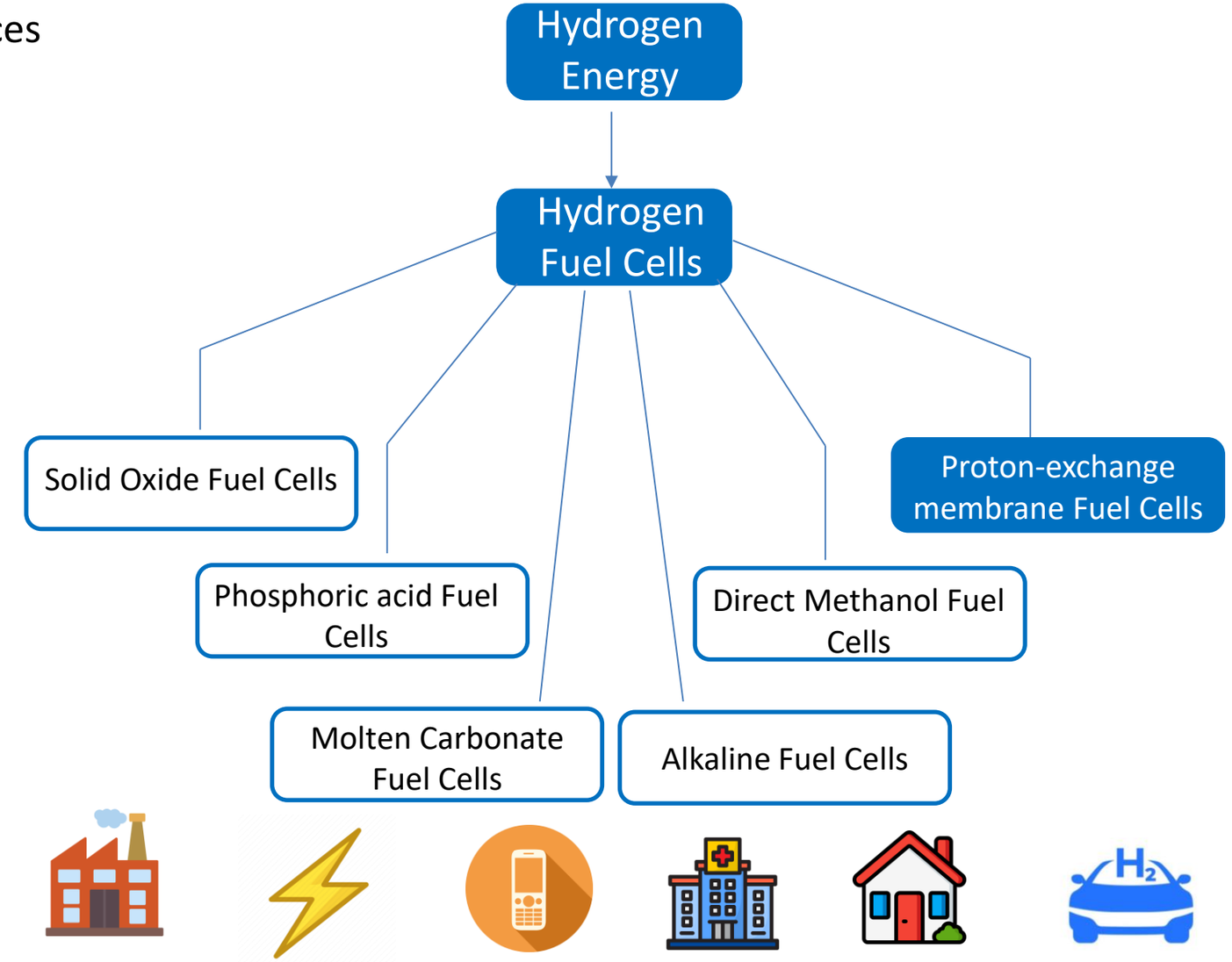
More than 80% of South Africa's electricity comes from coal.

Sustainable Energy Solutions

Transition into Renewable Energy Sources



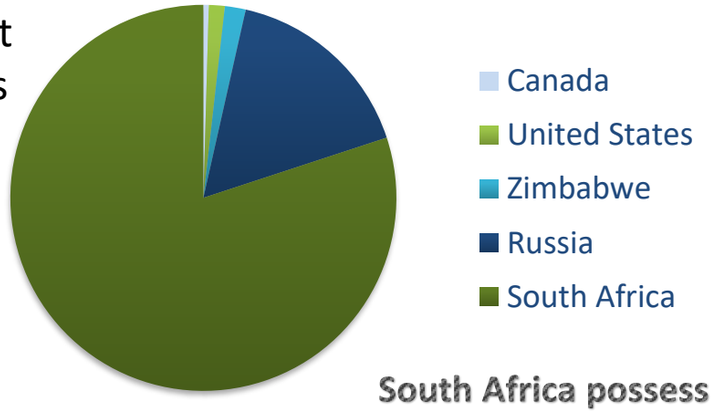
- Meet rising energy demands
- Decrease reliance on fossil fuels
- Decrease CO_2 emission



Why Proton-Exchange Fuel Cell (PEMFC) ?

- ✓ High Power Density (0.6 – 1,0 W/cm^2)
- ✓ Quick start-up (< 30s in automotive applications)*
- ✓ Operates at low temperature (60 – 90 °C)
- ✓ Reliable power solution – mitigate power cuts
- ✓ Backup power supply in hospitals, schools and businesses – reduce reliance on diesel generators
- ✓ Off-grid power supplies – support rural areas
- ✓ Uses Pt-based Catalyst – SA has the largest PGM reserves in the world

Global Pt Reserves

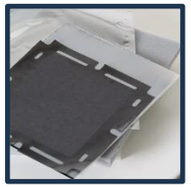


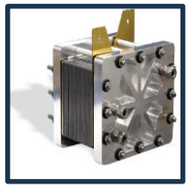
Jaganmohan M, Statista, 2024

South Africa possess more than 70% of the global Pt reserves


Pt


Catalyst


Membrane Electrode Assembly

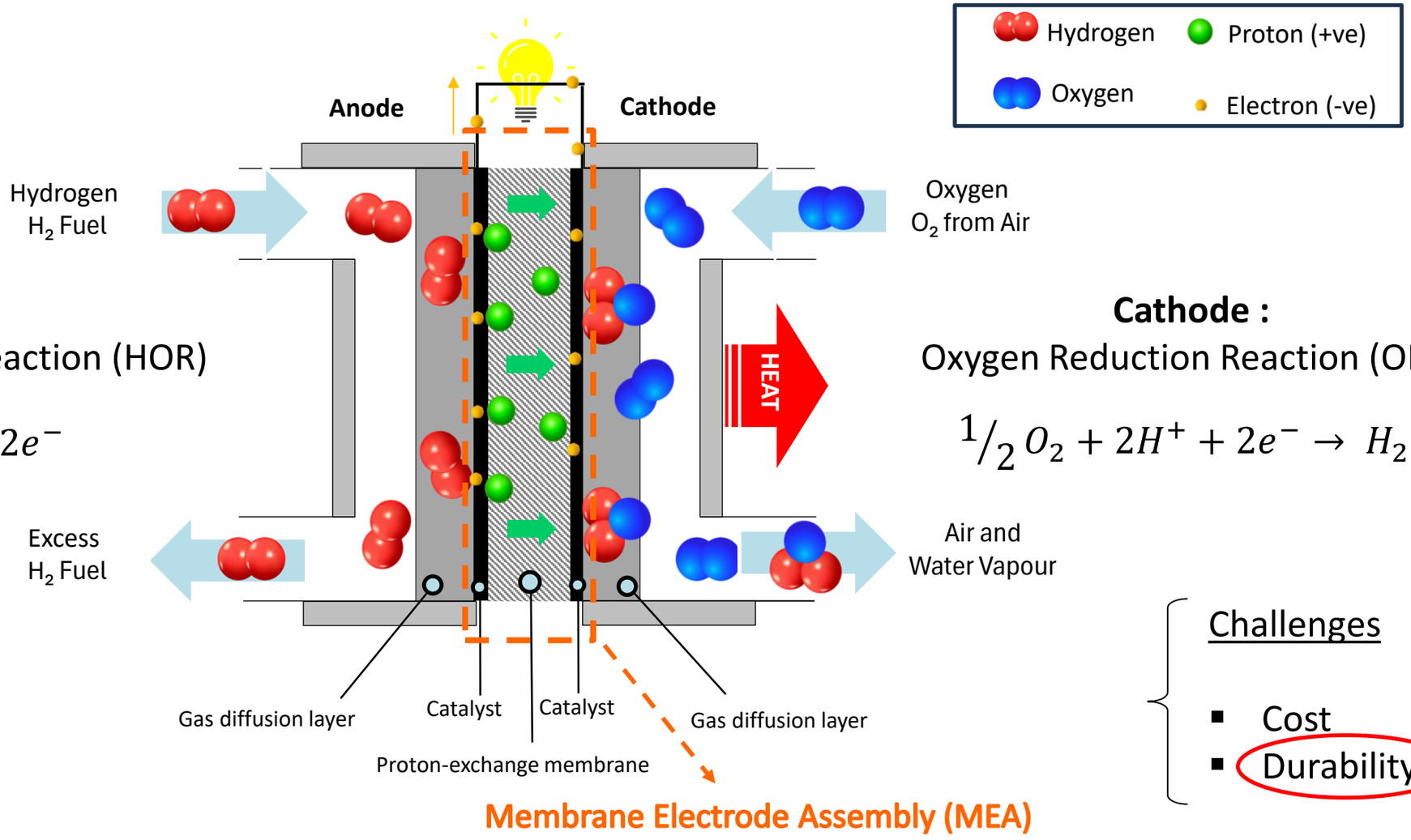

Fuel Cell Stack

Mineral Beneficiation Value Chain

**Yang X, Power Sources, 2022*

catalysis institute | UNIVERSITY OF CAPE TOWN CENTRE FOR CATALYSIS RESEARCH | MINTEK | science & innovation Department: Science and Innovation REPUBLIC OF SOUTH AFRICA

Proton Exchange Membrane Fuel Cell



Anode :
Hydrogen Oxidation Reaction (HOR)

$$H_2 \rightarrow 2H^+ + 2e^-$$

Cathode :
Oxygen Reduction Reaction (ORR)

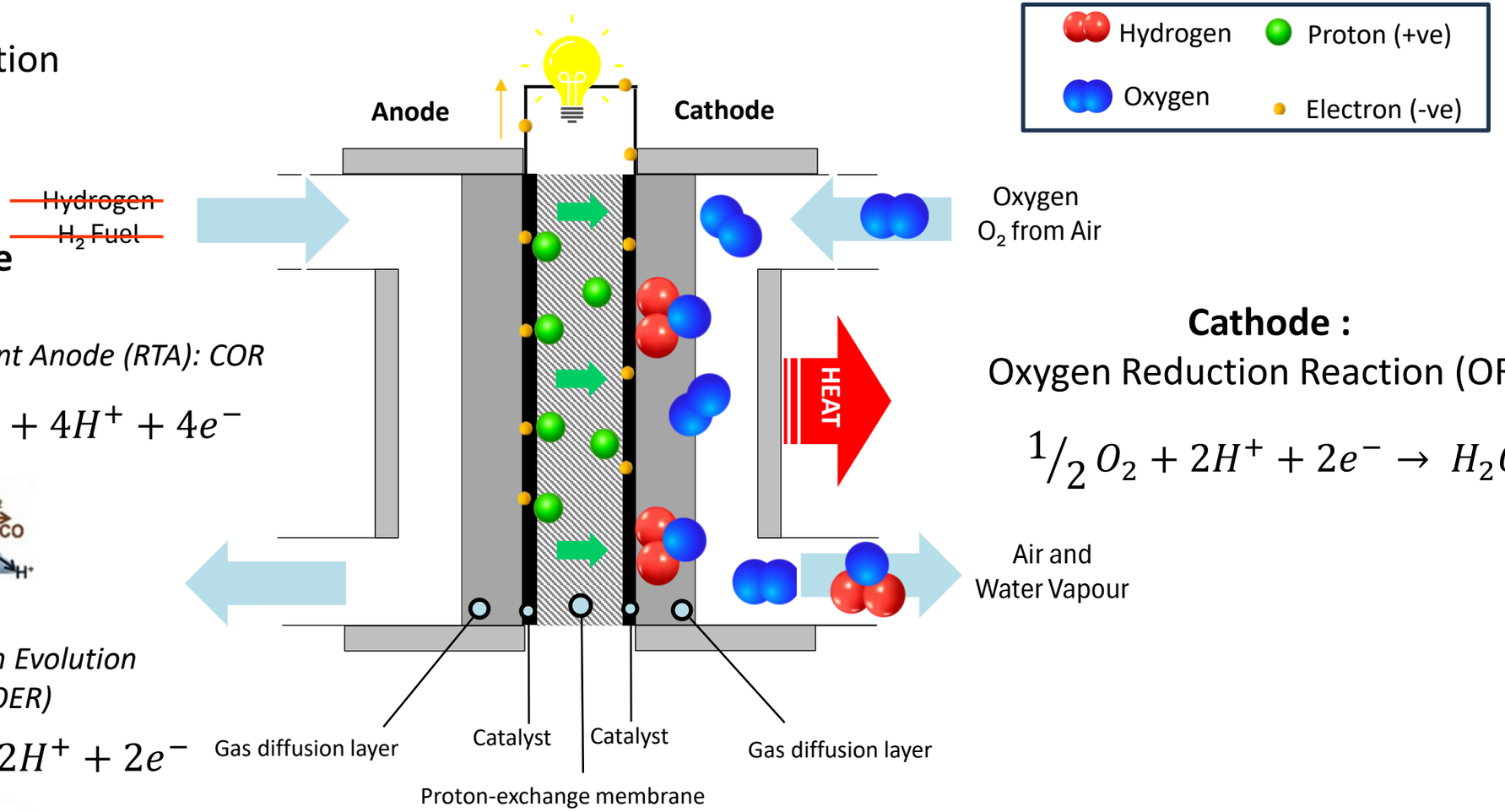
$$^1/_2\, O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

Challenges

- Cost
- Durability

Reversal Tolerance

Hydrogen Starvation



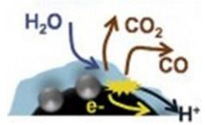
Cathode :

Oxygen Reduction Reaction (ORR)

$$^1/_2\, O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

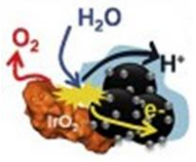
Without Reversal Tolerant Anode (RTA): COR

$$C + 2H_2O \rightarrow CO_2 + 4H^+ + 4e^-$$



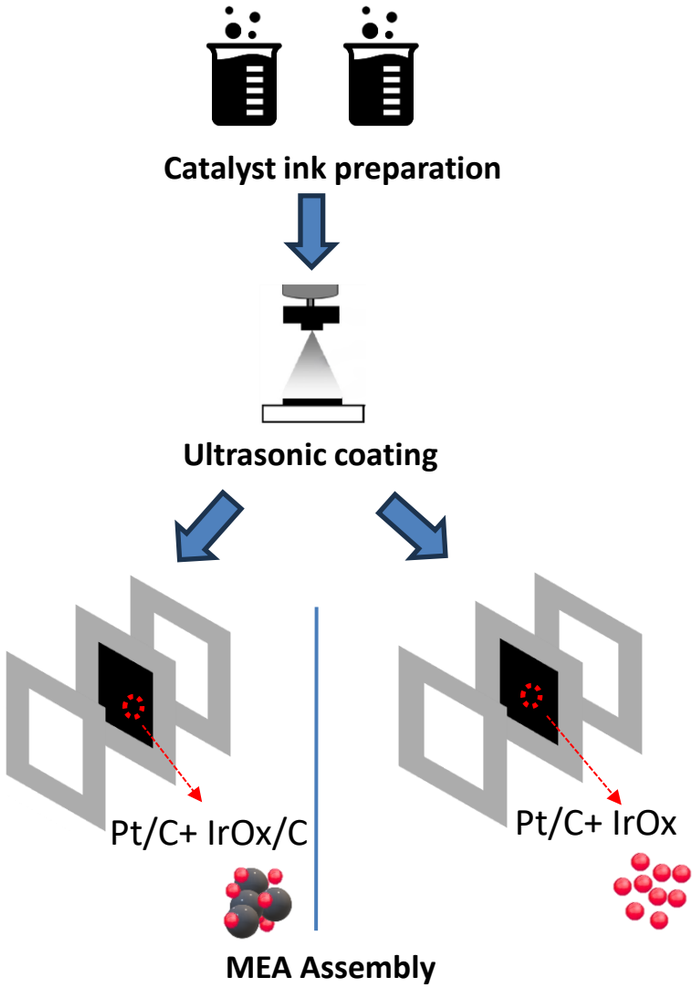
With RTA: Oxygen Evolution Reaction (OER)

$$H_2O \rightarrow {}^1/_2\, O_2 + 2H^+ + 2e^-$$



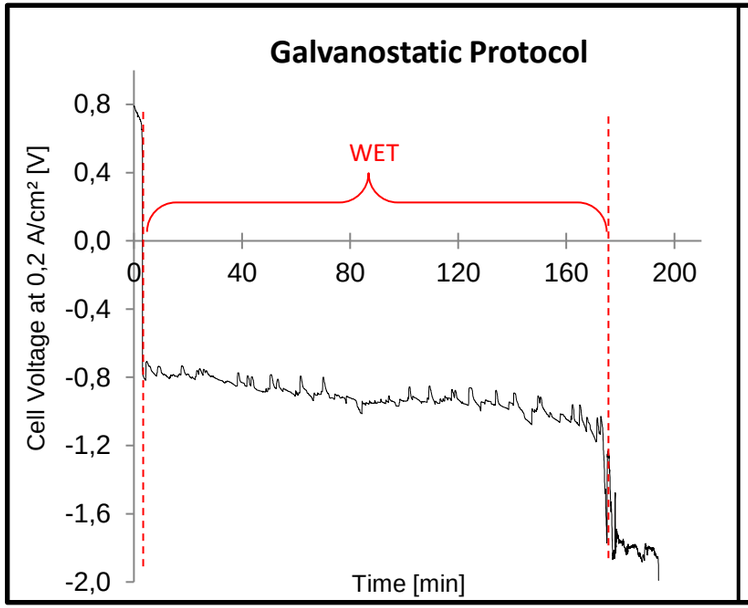
Methodology

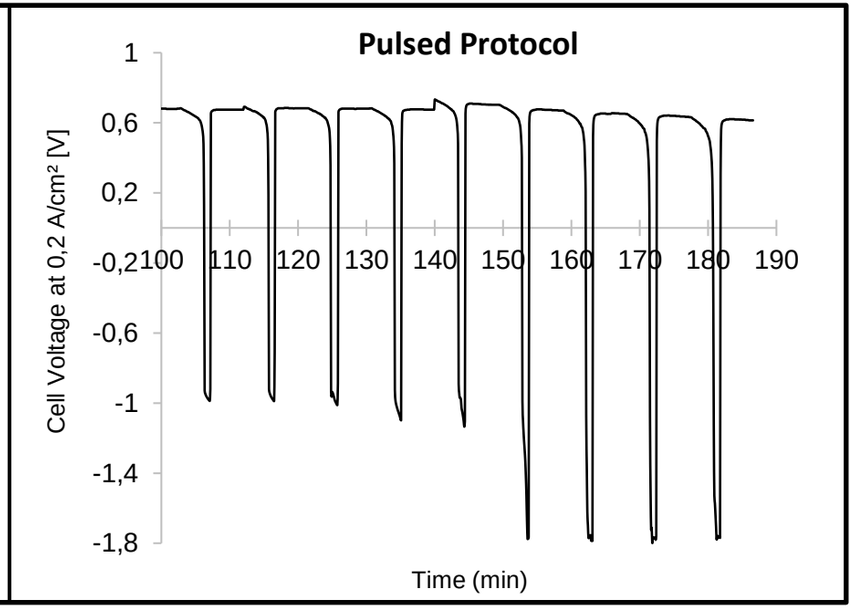
MEA Preparation



Testing Protocol

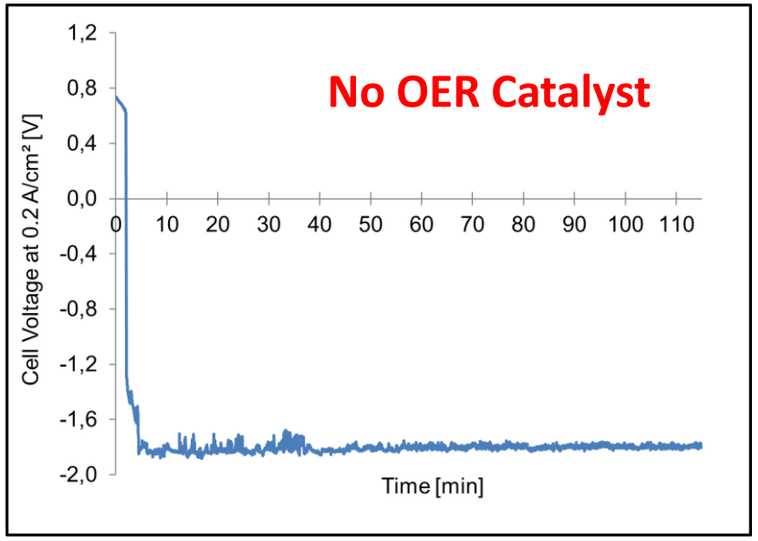
- Single Cell Testing.
- Accelerated Stress Test (AST) - H_2 starvation
  - Galvanostatic Protocol
  - Pulsed Protocol
- Water electrolysis time (WET) – the duration the cell is performing water electrolysis under hydrogen starvation operation conditions.

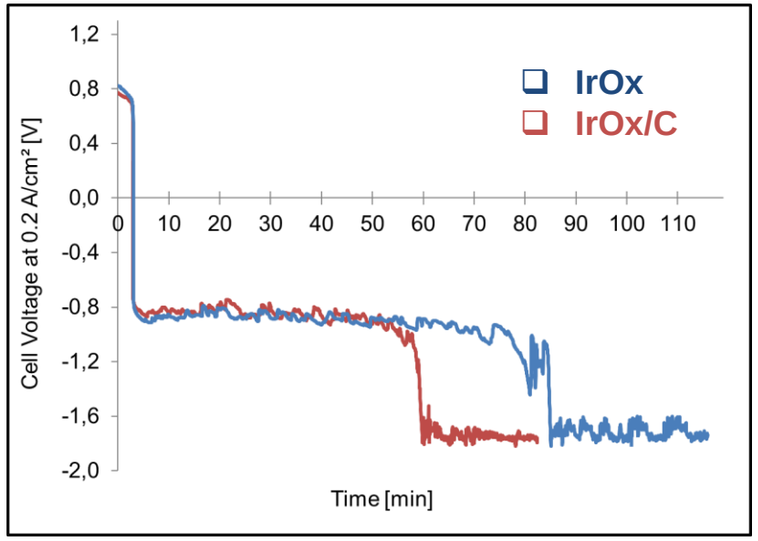




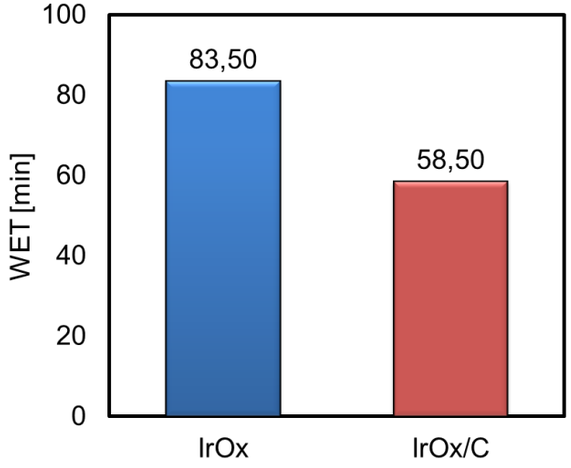
Results – Galvanostatic Protocol

Galvanostatic Reversal Event



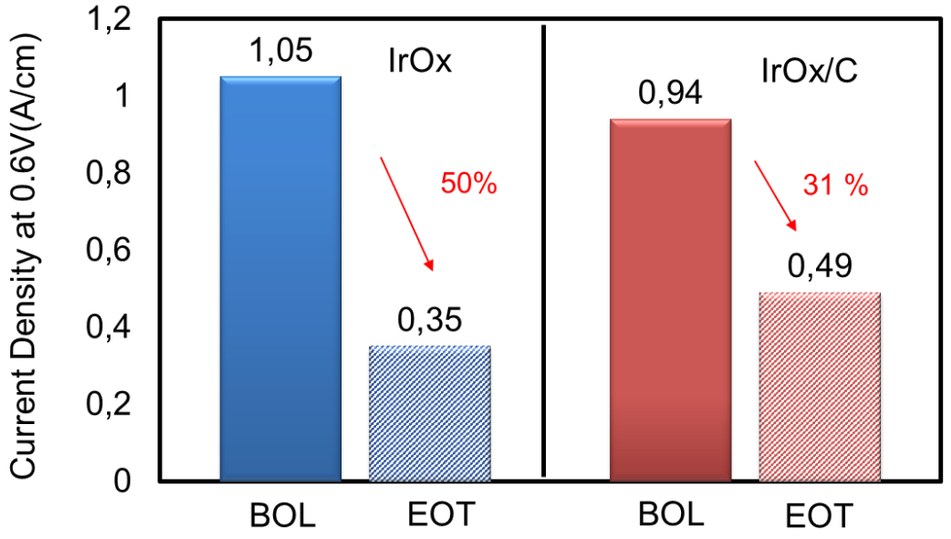


- The system without OER Catalyst immediately initiates carbon corrosion upon H_2 starvation.
- The system with OER catalyst initially promotes water electrolysis, however, over time transitions into carbon corrosion.
- Which MEA anode catalyst layer design is better?

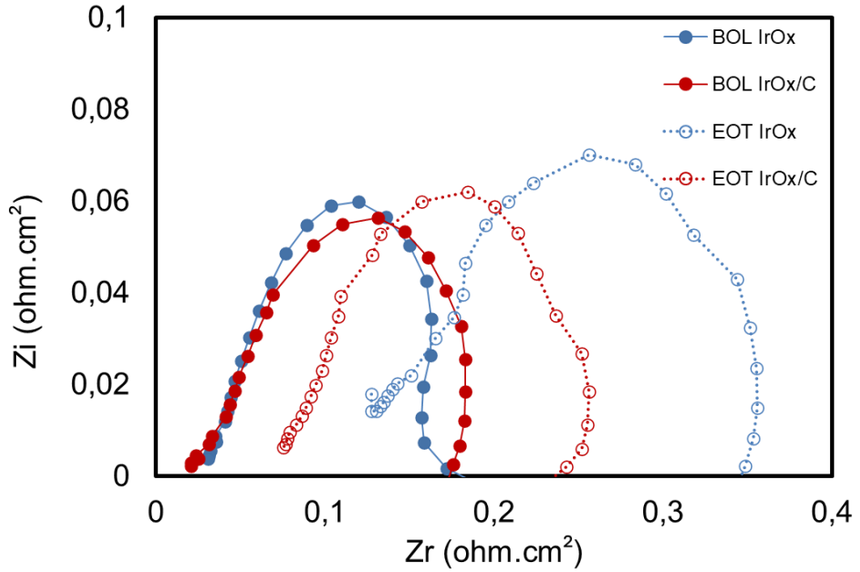


Results – Galvanostatic Protocol

Drop in performance from BOL to EOT (current density at 0,6 V)



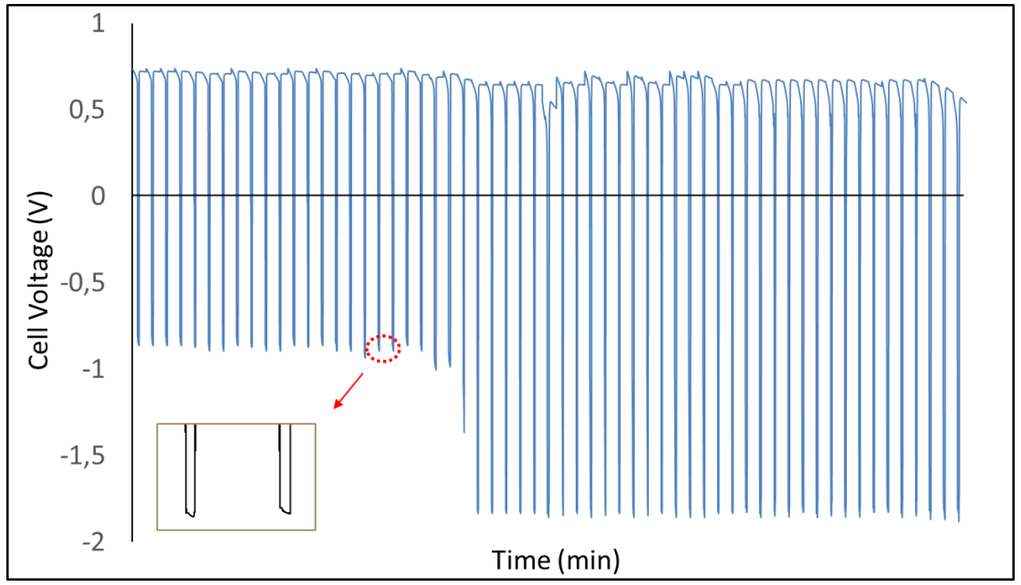
Electron Impendence Spectroscopy at 0,1 A/cm^2



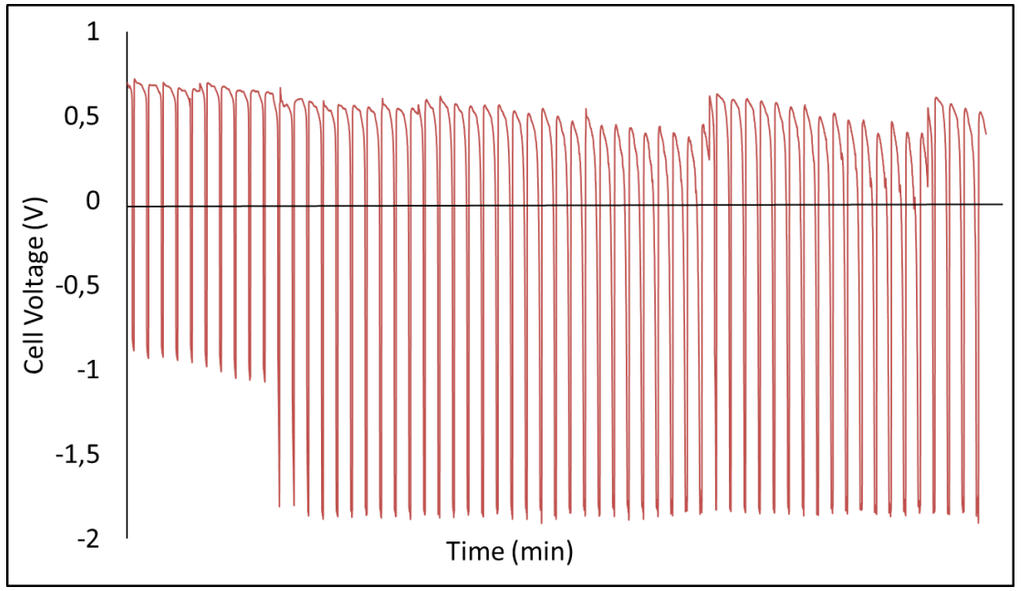
- MEA with IrOx was overall exposed to more carbon corrosion because it lasted longer in reversal conditions.
- There is a shift in the Nyquist plot from BOL to EOT exhibiting an increase in Ohmic and charge transfer resistance.
- A greater increase in ohmic resistance is observed in the MEA with IrOx catalyst due to more extensive degradation of the anode catalyst layer.

Results – Pulsed Protocol

IrOx Pulsed Reversal Events



IrOx/C Pulsed Reversal Events

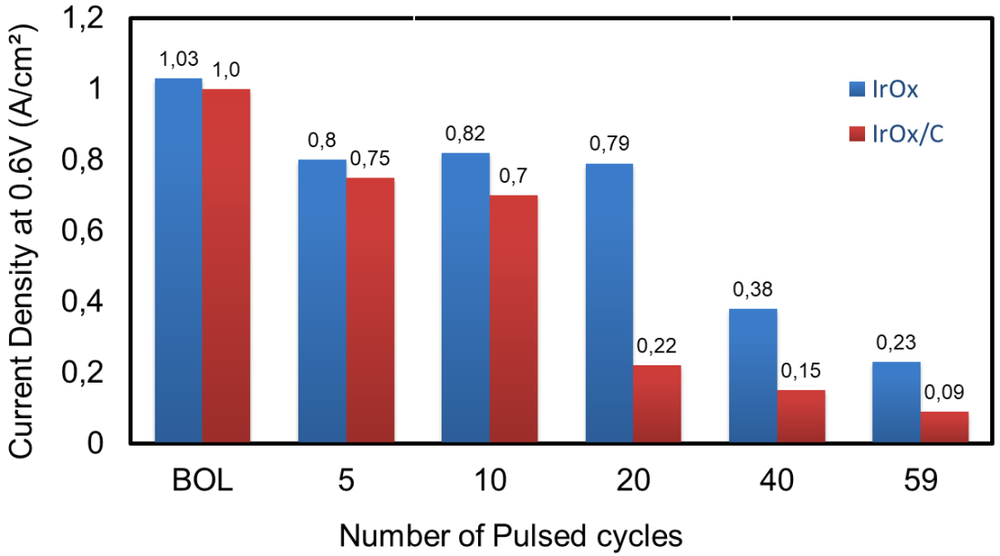


	IrOx/C Supported	IrOx Unsupported
WET [minutes]	10	24

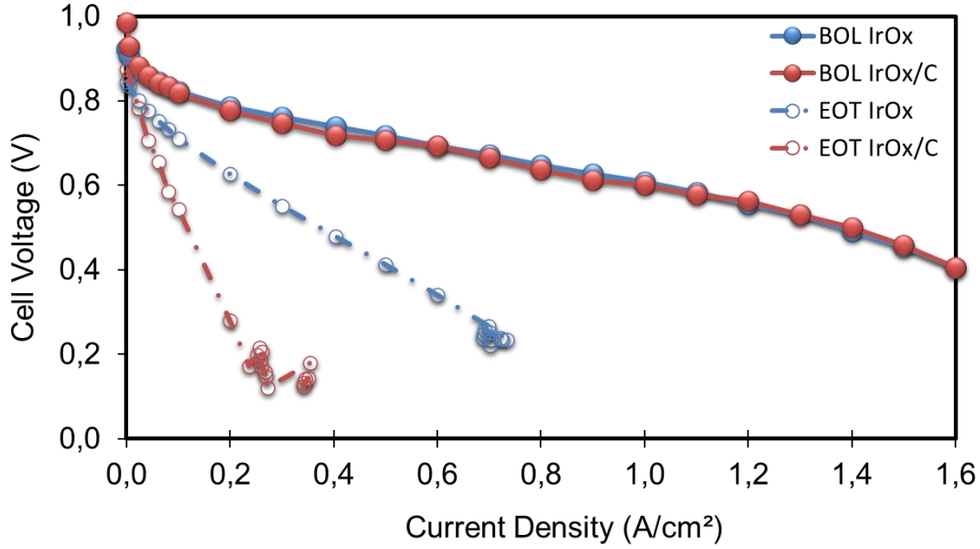
- Both systems were subjected to the **same number of pulses** to directly compare the performance degradation.
- Pulsed protocol is more damaging to the MEA compared to galvanostatic protocol (shorter water electrolysis time)

Results – Pulsed Protocol

Performance from BOL to EOT – after 59 pulses
(current density at 0,6 V)



BOL and EOT Polarization Curve



- The current density decreases with a number of pulses because the system is degrading.
- MEA with IrOx/C indicates a larger degradation after the total number of pulses.
- MEA with IrOx exhibits better durability under the pulsed reversal conditions, likely due to higher catalyst stability.

Conclusions

- Addition of OER catalyst in MEA anode catalyst layers improves anode durability during hydrogen starvation.
- The OER catalyst does not remain indefinitely active – once it can no longer sustain water electrolysis, the system defaults to a more detrimental carbon oxidation reaction.
- The pulsed protocol allows for a direct comparison between two systems and is more detrimental to the system.
- MEA designs using IrOx outperforms MEA with IrOx/C as confirmed by galvanostatic and pulse testing.

Future Work

- Investigate IrOx supported on different materials (e.g oxides), to potentially extend water electrolysis duration ad delay anode catalyst layer degradation.
- Gain understanding of the OER catalyst deactivation mechanism.

Acknowledgements

science & innovation
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Thank you for your attention!

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