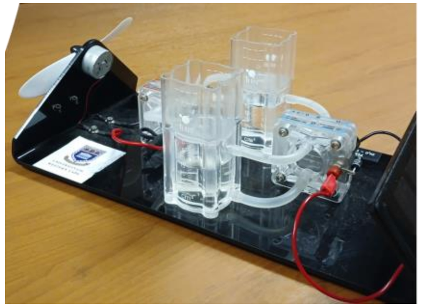
Synthesis, Characterization, and Testing of Ru-Modified IrO_2 ($Ir_xRu_yO_2$) Catalyst in a Laboratory-Scale PEMWE



Presenters: Dr D Zide, Prof BJ Bladergroen, Dr S Chidziva, Prof S Pasupati, Mr A Sinto

2nd Southern African Hydrogen and Fuel Cell Conference 2025; 7-8 April; Southern Sun Rosebank, Johannesburg

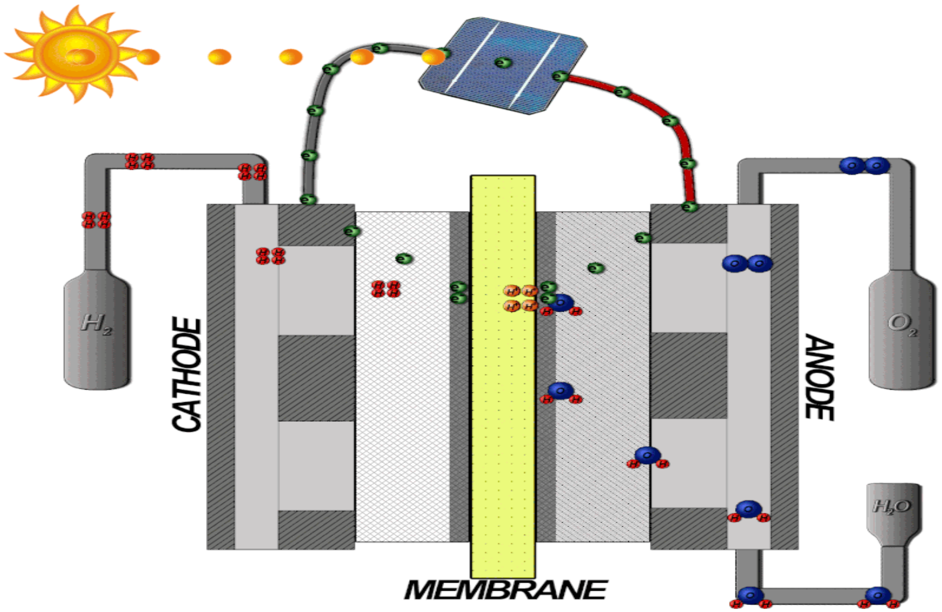
INTRODUCTION: Why Green Hydrogen is Important for South Africa

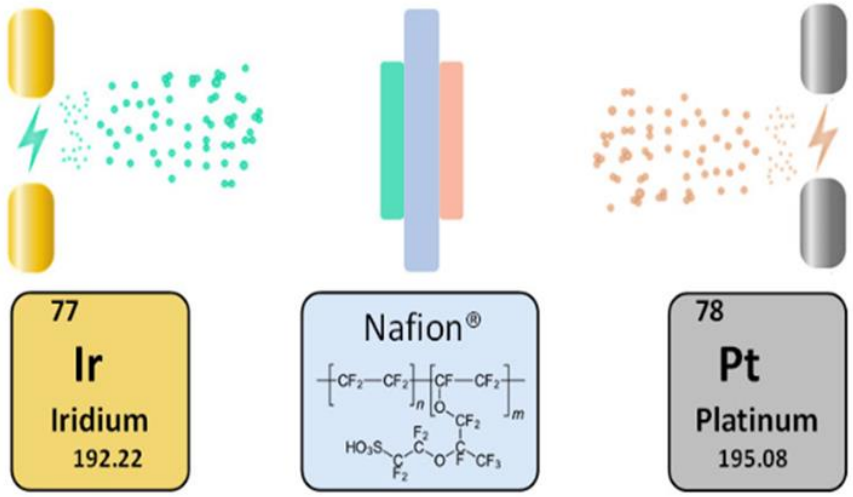
Existing coal-fired power station at Mpumalanga province of South Africa. Pollution from fossil fuel consumption costs South Africans hundreds of billions of rands in public health damage and environmental loss each year (*Sources:* [18,19]).

Sourced: Anekwe, et.al., (2024): https://doi.org/10.1177/00368504241237347;
https://pmc.ncbi.nlm.nih.gov/articles/PMC11024586/

- Abundant solar and wind resources enable cost-effective green hydrogen production.
- Supports decarbonization of hard-to-abate sectors: mining, steel, and heavy transport.
- Aligns with national policies like the Hydrogen Society Roadmap and JET-IP.
- Drives industrial innovation, job creation, and export-led growth.
- Enhances energy security and positions SA as a global hydrogen hub.

JUSTIFICATION OF THE STUDY: Cost Challenges in PEM Electrolyzer Technology



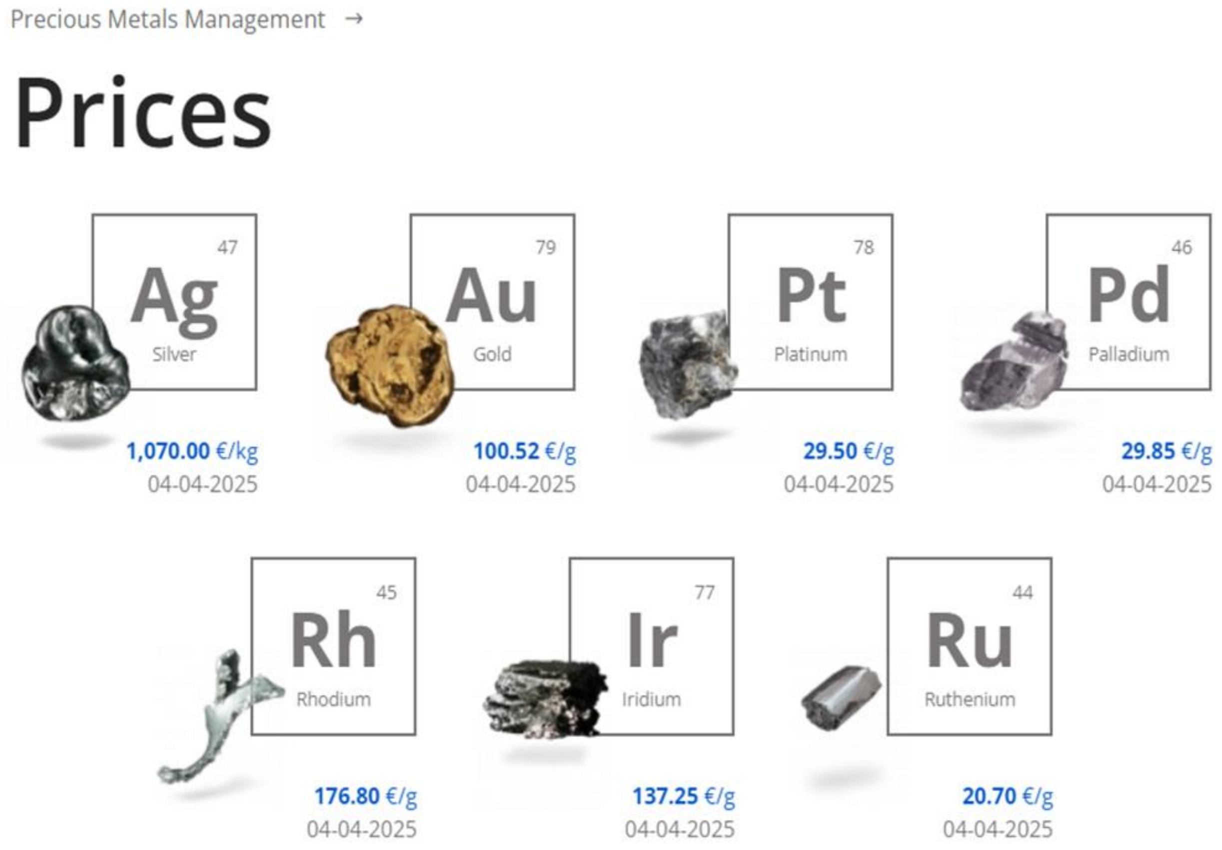


- PEMWE systems are efficient but more expensive.
- It require scarce and costly materials like Ir and Pt
- **Iridium is extremely rare**, with limited global supply and volatile pricing
- MEAs and system components are complex and mostly imported, raising costs.
- Local catalyst R&D is limited but growing.

OUR FOCUS: Aim and Objectives of the Study

- Our research explores cost-reduction strategies by partially replacing iridium with ruthenium, which is less expensive yet still catalytically active. If scaled, such innovations can help lower the overall cost of PEMWEs and enable wider adoption of green hydrogen in South Africa and beyond.

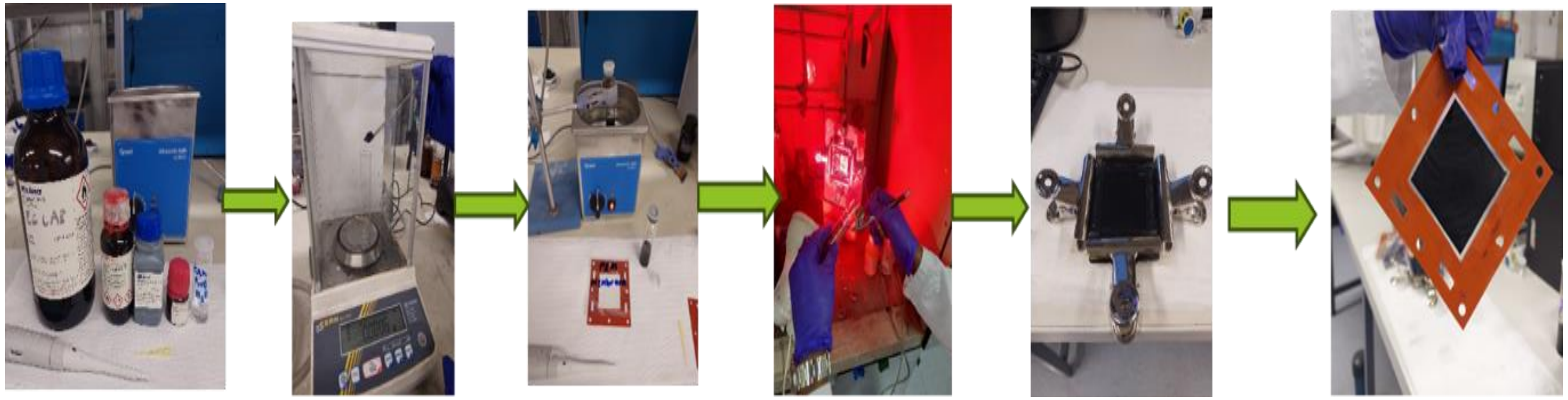
Ru is 85% Cheaper when compared to Ir



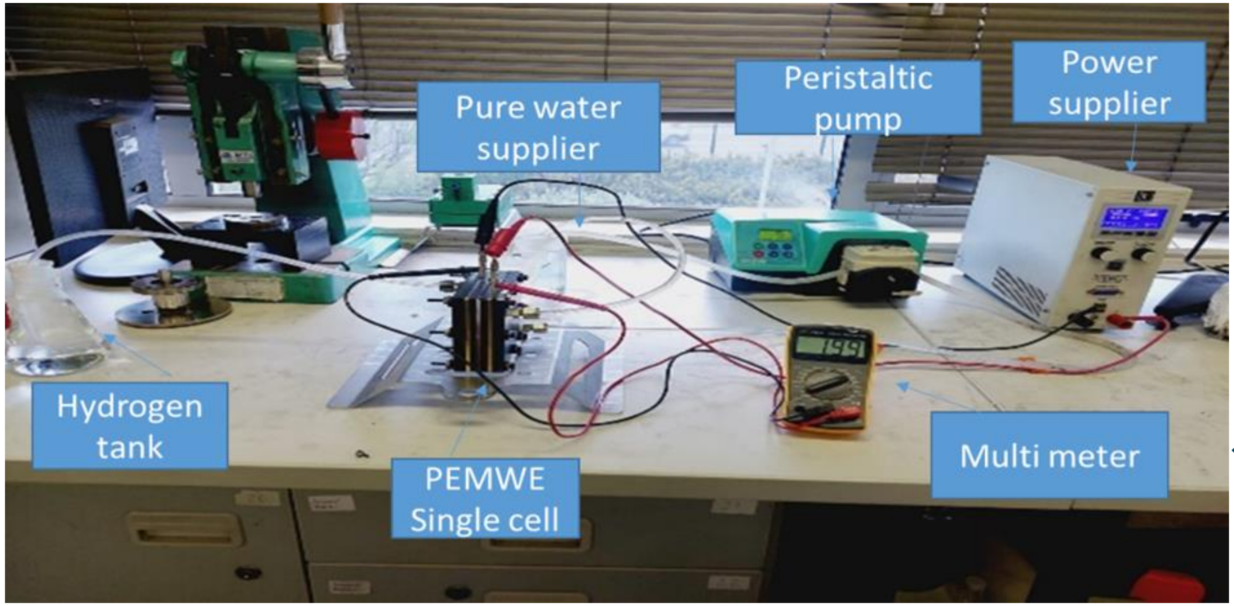
Sourced at Umicore (2025/04/06); https://pmm.umicore.com/en/prices/

OUR FOCUS: Aim and Objectives of the Study

PEM Cell Electrode Evaluation: Electrode Production_Ink, CCMs, MEAs, Cell Assembling



- ❑ Ink Preparation
- ❑ CCM Production
- ❑ MEA Fabrication
- ❑ Cell Assembling
- ❑ Cell Evaluation Performance

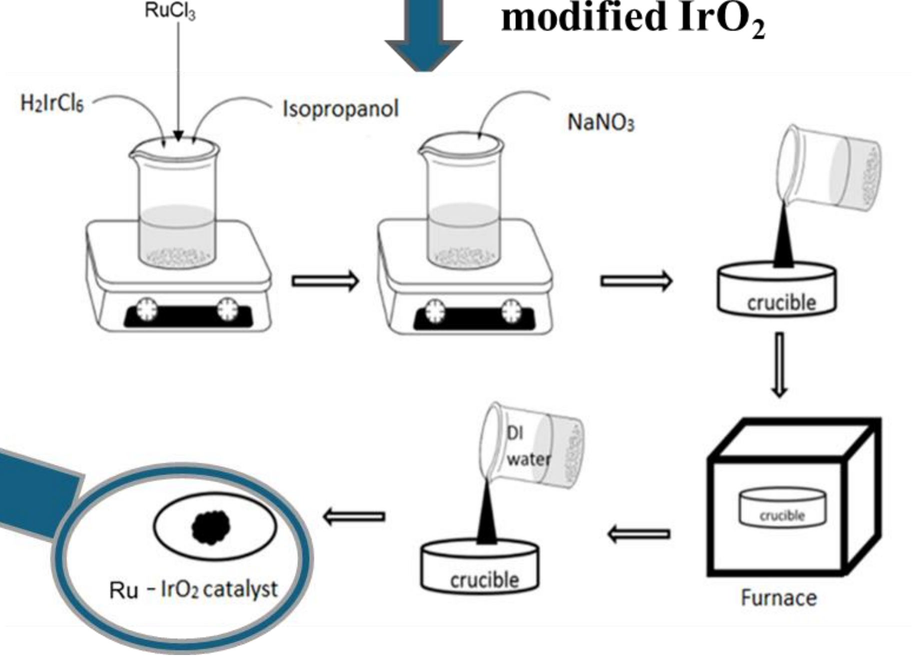


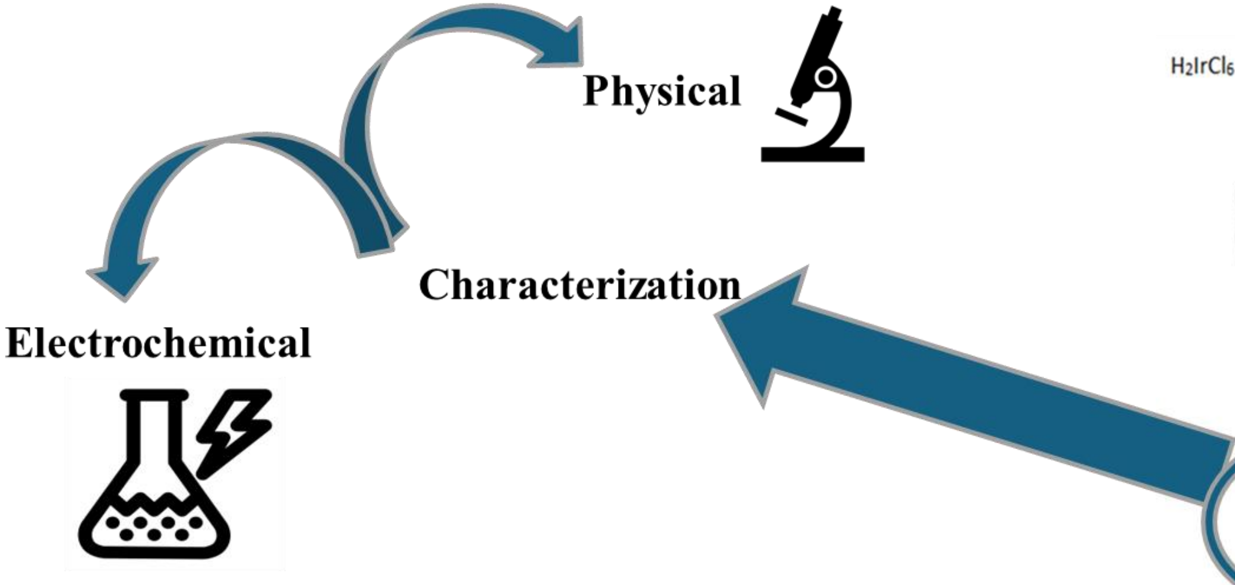
METHODOLOGY: Synthesis Process

Modified Adams Fusion Method

- ❑ Simplicity
- ❑ Easily removable NaCl salt by-product
- ❑ Scalability

Synthesis of Ru-modified IrO_2





RESULTS: Physical Characterizations

<u>XRD:</u> X-ray diffractometer D8-advance with Cu-Kα radiation from Bruker with the EVA software

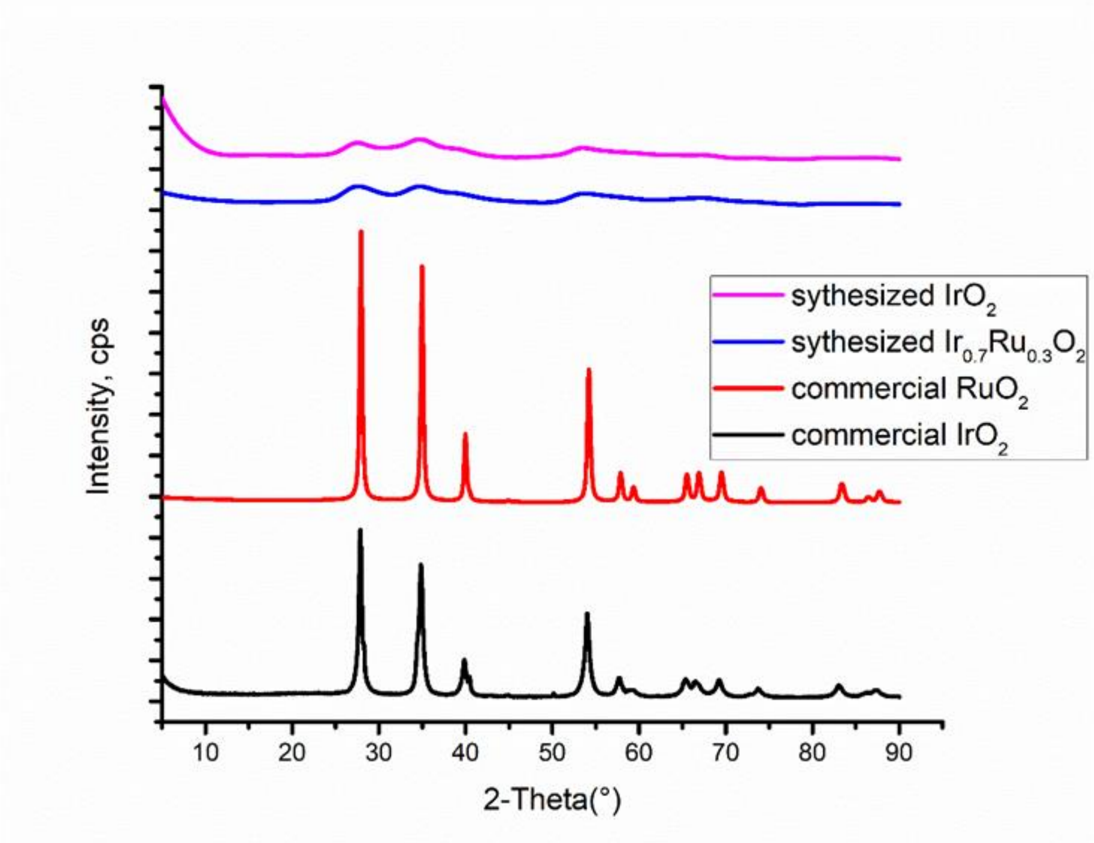


Figure1: XRD pattern comparison of commercial and synthesized electrocatalysts.

<u>SEM:</u> High-resolution scanning electron microscopy (HR-SEM) (300 nm)

A - Commercial IrO_2　　**B – Synthesized IrO_2**

C - Commercial RuO_2　　**D – Synthesized $Ir_{0.7}Ru_{0.3}O_2$**

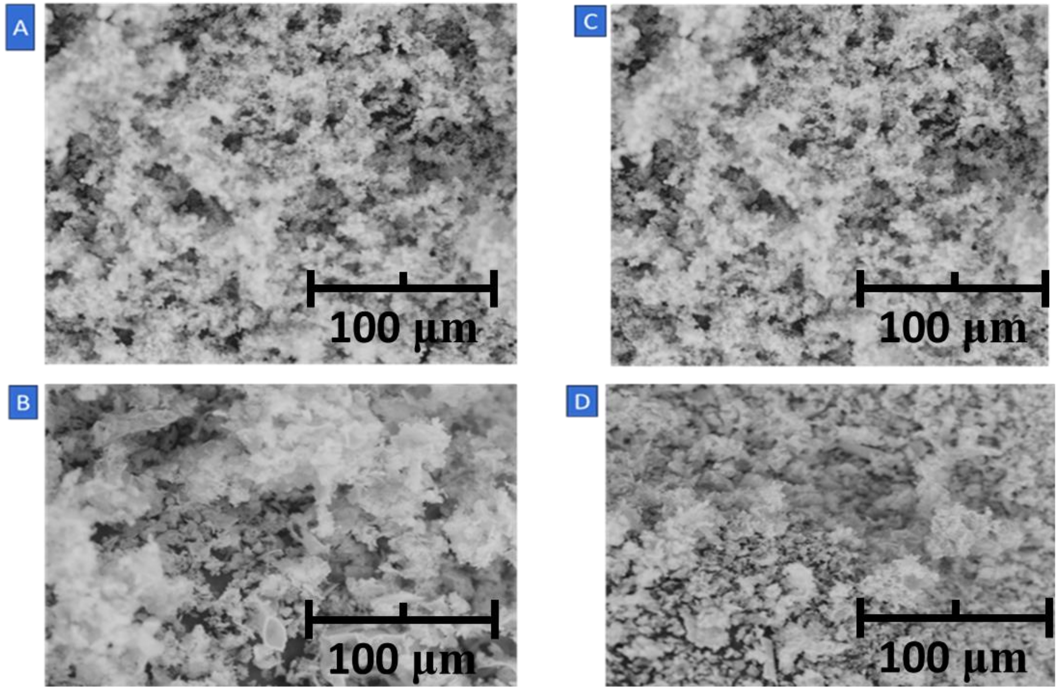


Figure 2: SEM images of electrocatalysts - (A) Commercial IrO_2, (B) Synthesized IrO_2, (C) Commercial RuO_2, (D) Synthesized $Ir_{0.7}Ru_{0.3}O_2$.

RESULTS: Electrochemical Characterizations Parameters

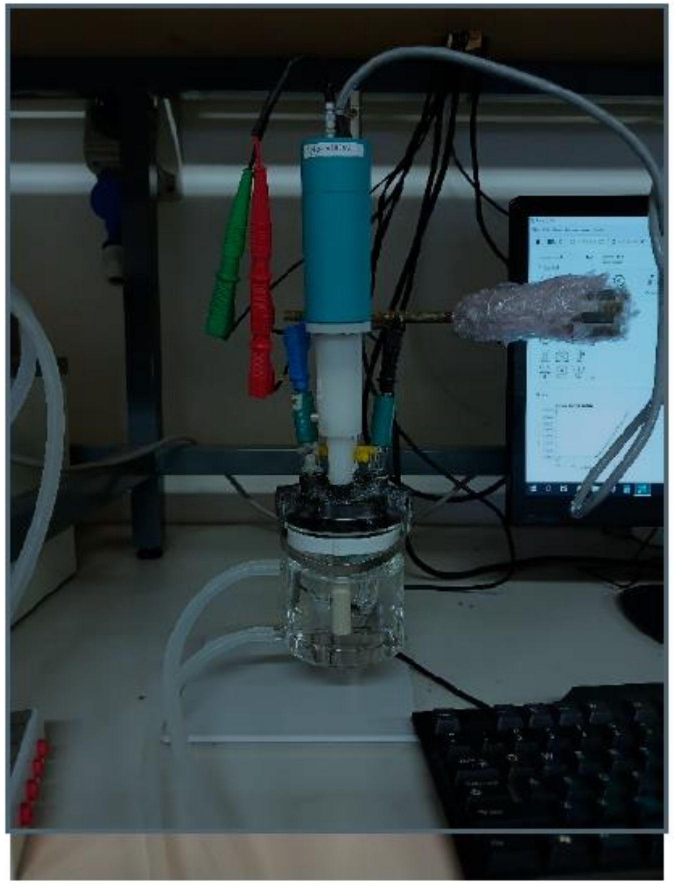


Table 1. The parameters of the CV (Cyclic voltammetry) analysis [31].

Start potential	0.02 V
Upper vertex potential	1.2 V
Lower vortex potential	−0.2 V
Stop potential	0.02 V
Number of scans	3
Scan rate	0.02 V/s
Step	0.00244 V
Interval time	0.12207 s

Table 2. The parameters of the LSV (Linear sweep voltammetry) analysis [31].

Start potential	0.8 V vs. RHE
Stop potential	1.8 V vs. RHE
Scan rate	0.002 V/s
Step	0.00244 V
Interval time	1.2207 s
Current range	1 mA–100 nA
Rotation speed	1600 rpm

Table 3. The parameters of CP (Chronopotentiometry) analysis [31].

Applied current	0.02 A/cm^2
Maximum cutoff voltage	1.8 V vs. RHE
Rotation speed	1600 rpm

RESULTS: Electrochemical Characterizations

Cyclic Voltammetry

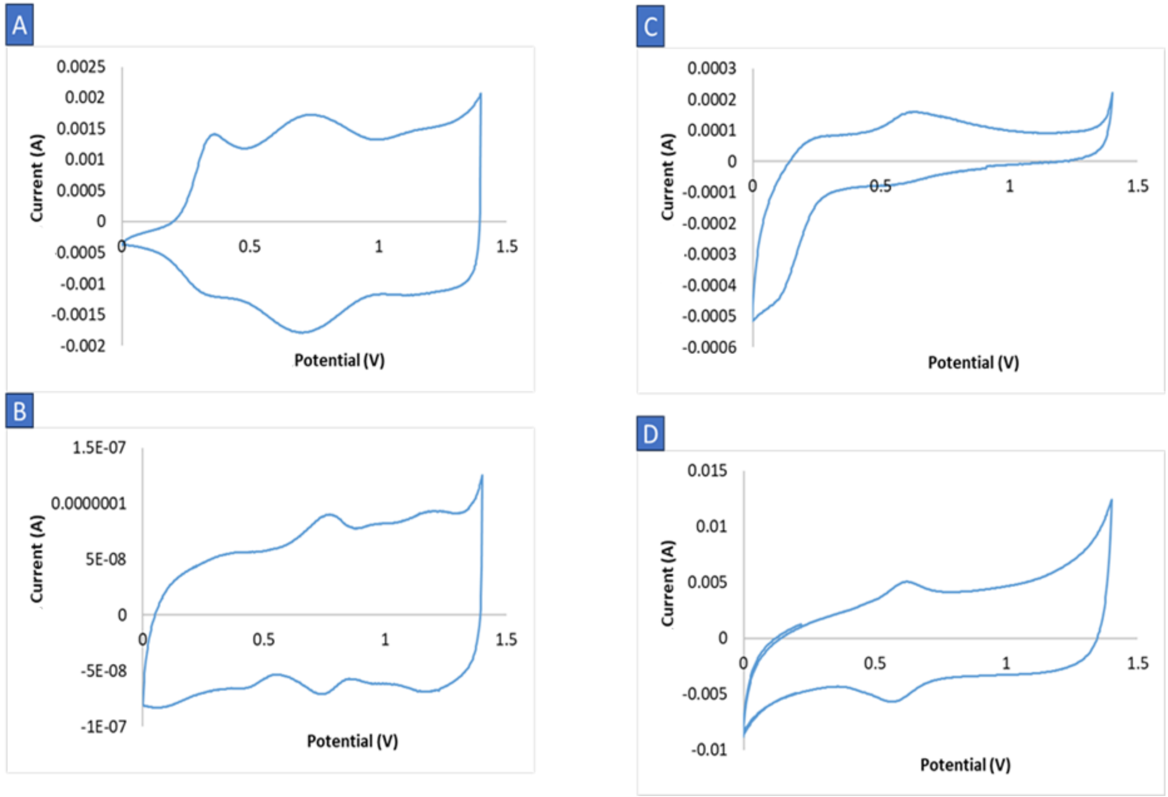


Figure 3: Cyclic voltammogram of four electrocatalysts. (A) Commercial iridium oxide. (B) Synthesised iridium oxide (C) Commercial ruthenium oxide. (D) Synthesised ruthenium modified iridium oxide.

Linear Sweep Voltammetry

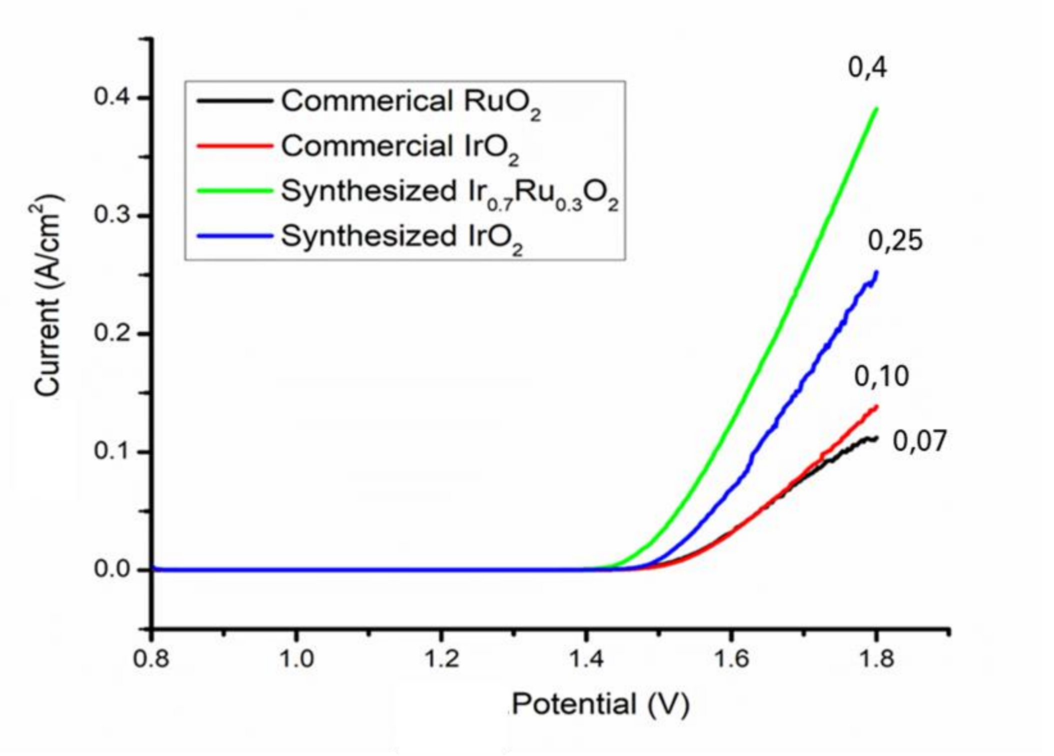


Figure 4: LSV plots of electrocatalysts (commercial IrO_2, commercial RuO_2, synthesised IrO_2 and synthesised $Ir_{0.7}Ru_{0.3}O_2$) at 0.002 V/s.

RESULTS: Electrochemical Characterizations

Chronopotentiometry (ChronoP)

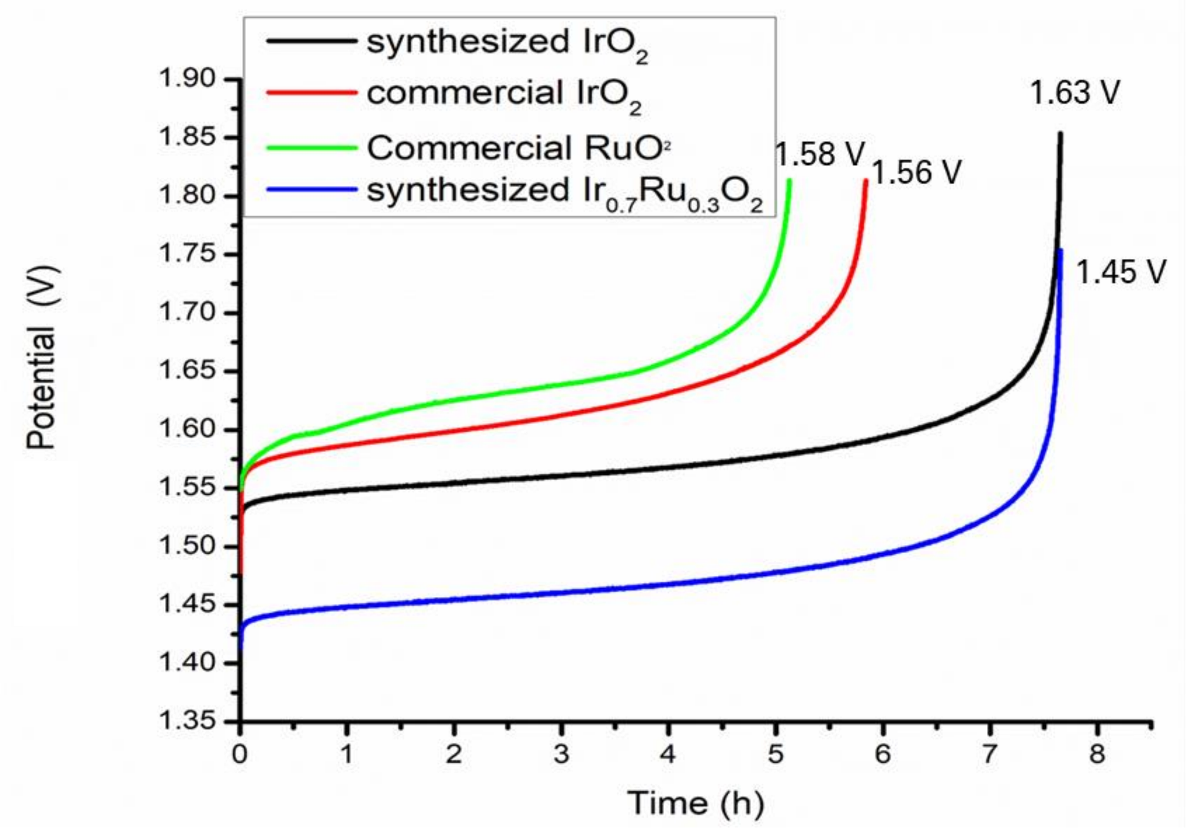


Figure 5: Chronopotentiometric stability of electrocatalysts - chrono of commercial IrO_2, commercial RuO_2, synthesised IrO_2 and synthesised $Ir_{0.7}Ru_{0.3}O_2$.

Evaluation of CCM performance

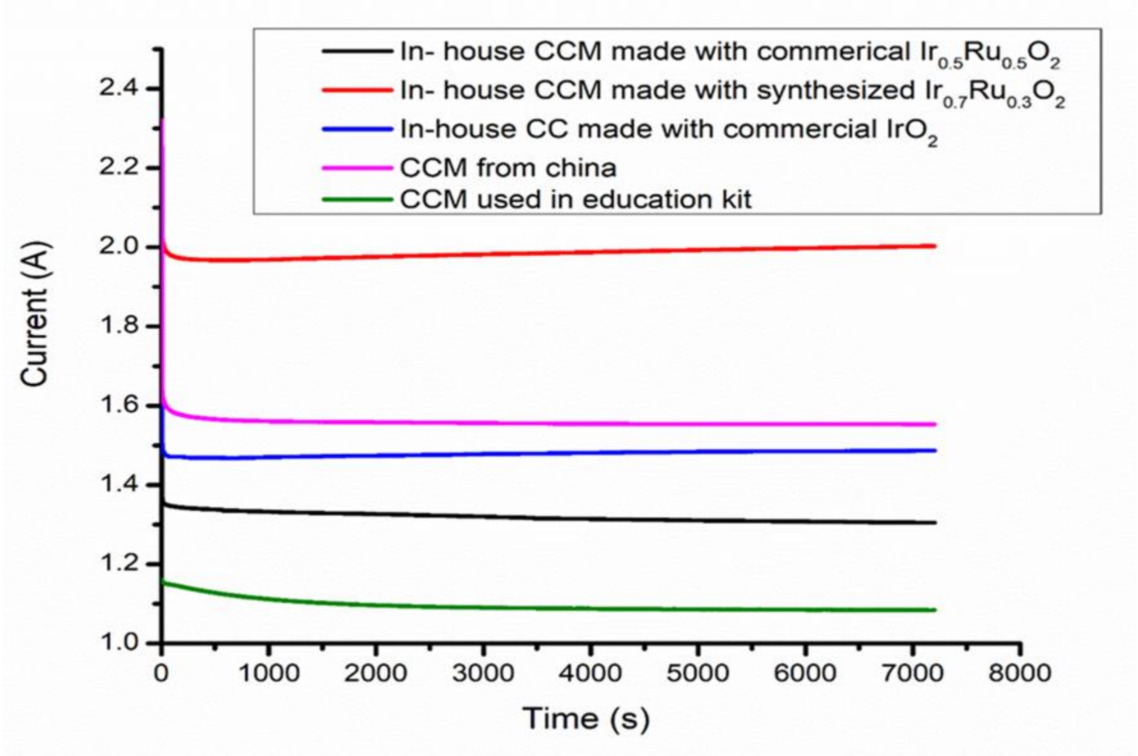


Figure 6: The evaluation performance of CCM coated with different catalysts.

RESULTS: Testing of membrane electrode assembly in real world

Fig. 7: Conducted in a controlled environment (Lab) using a single cell-based electrolyzer

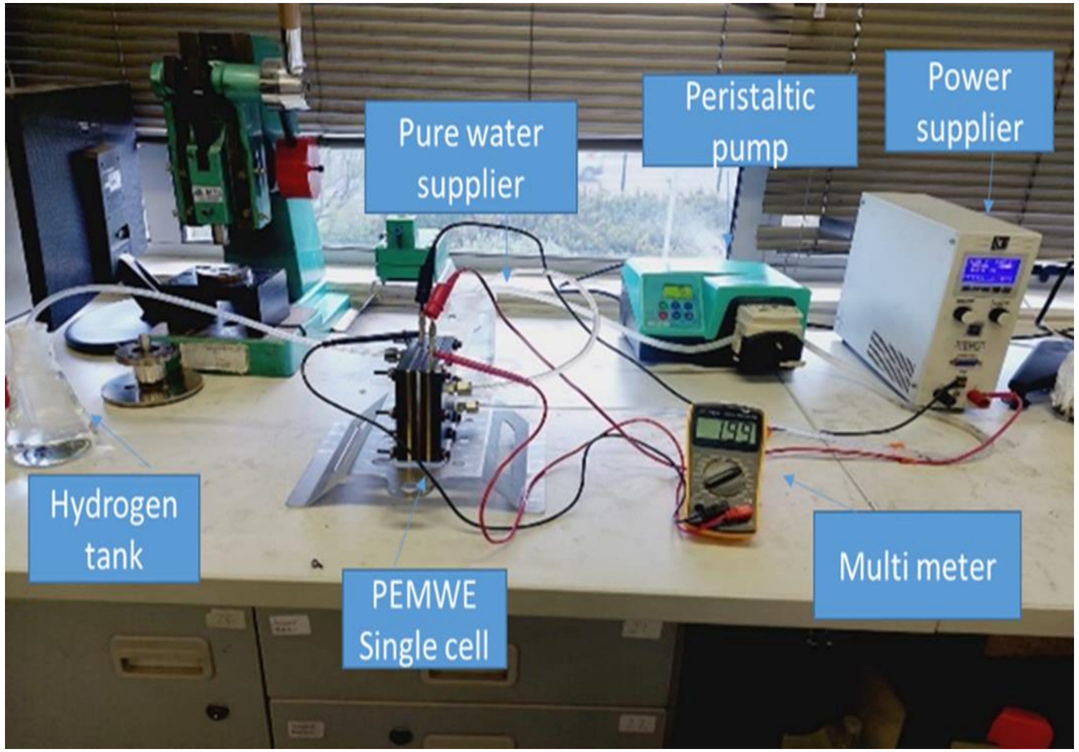


Fig. 8: Conducted in a noncontrolled environment (outside) using single cell-based electrolyzer

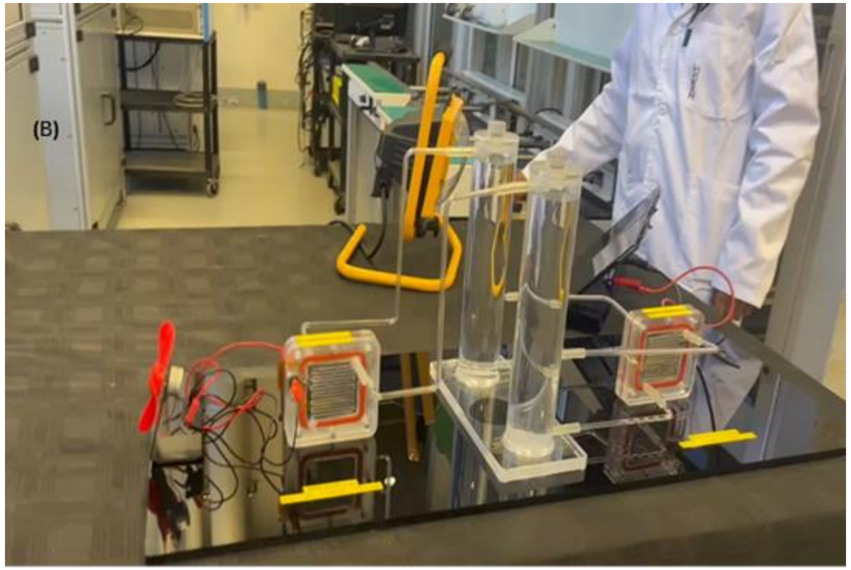


Fig. 9: Performed inside using an in-house PEM electrolyzer cell, H_2 and O_2 storage towers, a single-cell PEM fuel cell, and a fan acting as a load

CONCLUSION

- In conclusion, a synthesized Ru-modified IrO_2 was successfully prepared using the Adams Fusion Method and showed improved activity compared to unsupported IrO_2.
- Ruthenium was chosen as a secondary metal due to its low cost and high activity in OER.
- Considering the lower cost of secondary metals compared to iridium, this approach could significantly reduce the cost of the PEM electrolyzer.

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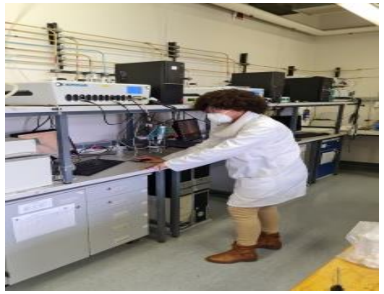

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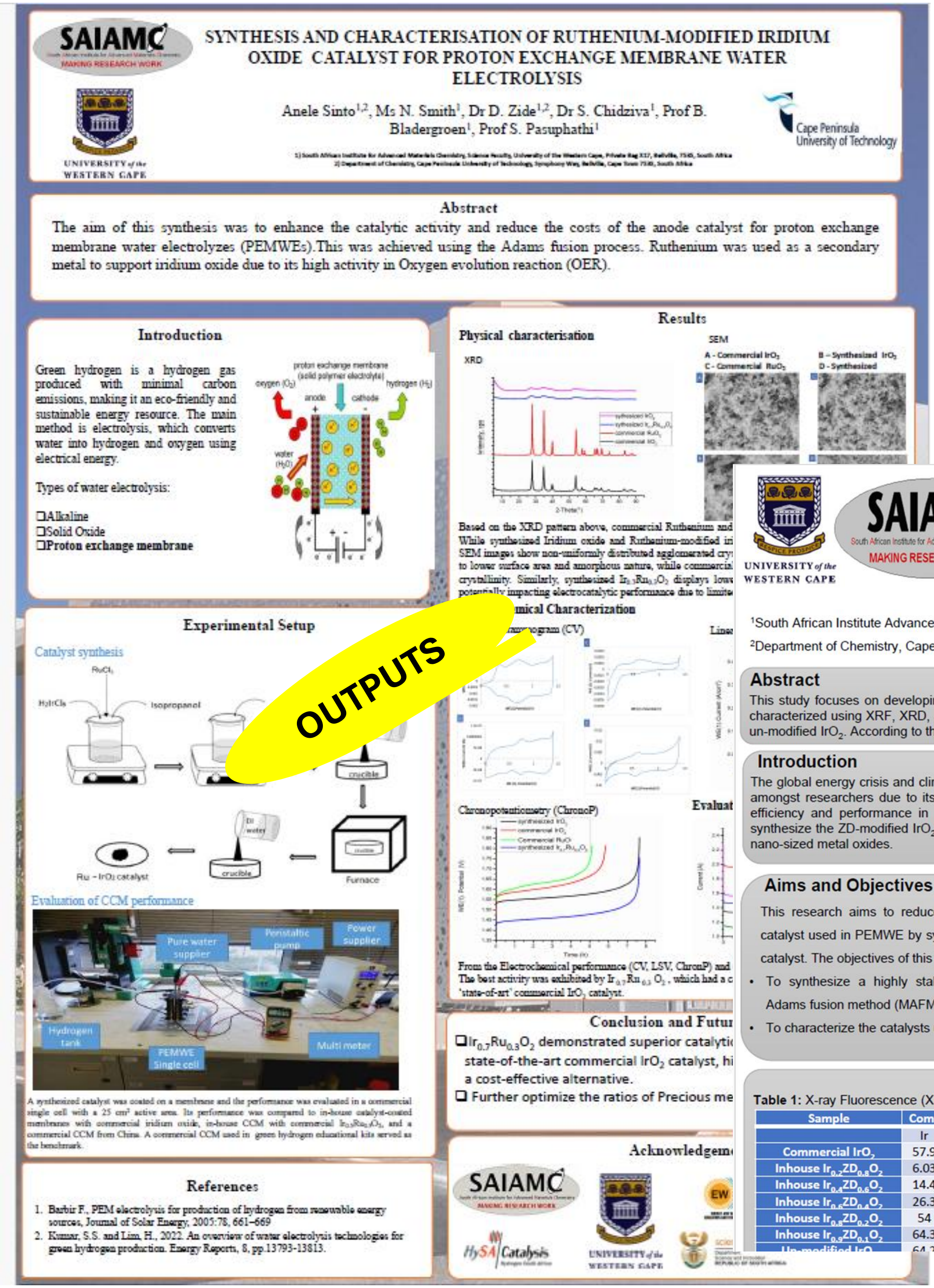
Technology demo at STEM

OUTPUTS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MAKING RESEARCH WORK
SYNTHESIS AND CHARACTERISATION OF RUTHENIUM-MODIFIED IRIDIUM OXIDE CATALYST FOR PROTON EXCHANGE MEMBRANE WATER ELECTROLYSIS
Anele Sinto1,2, Ms N. Smith1, Dr D. Zide1,2, Dr S. Chidziva1, Prof B. Bladergroen1, Prof S. Pasupathi1
UNIVERSITY of the WESTERN CAPE
Cape Peninsula University of Technology
Abstract
The aim of this synthesis was to enhance the catalytic activity and reduce the costs of the anode catalyst for proton exchange membrane water electrolyzes (PEMWEs).This was achieved using the Adams fusion process. Ruthenium was used as a secondary metal to support iridium oxide due to its high activity in Oxygen evolution reaction (OER).
Introduction
Green hydrogen is a hydrogen gas produced with minimal carbon emissions, making it an eco-friendly and sustainable energy resource. The main method is electrolysis, which converts water into hydrogen and oxygen using electrical energy.
Types of water electrolysis:
Alkaline
Solid Oxide
Proton exchange membrane
Results
Physical characterisation
XRD
SEM
Experimental Setup
Catalyst synthesis
Evaluation of CCM performance
Pure water supplier
Peristaltic pump
Power supplier
Hydrogen tank
PEMWE Single cell
Multi meter
Chronopotentiometry (ChronoP)
Conclusion and Futur
Further optimize the ratios of Precious me
Acknowledgem
References
1. Barbir F., PEM electrolysis for production of hydrogen from renewable energy sources, Journal of Solar Energy, 2005:78, 661–669
2. Kumar, S.S. and Lim, H., 2022. An overview of water electrolysis technologies for green hydrogen production. Energy Reports, 8, pp.13793-13813.


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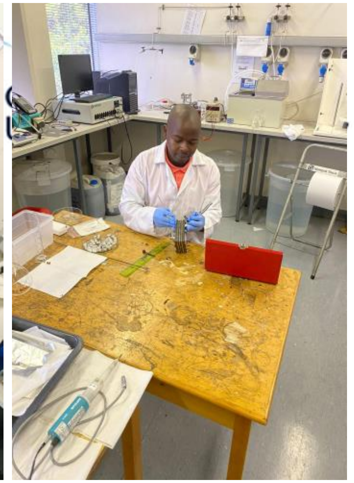

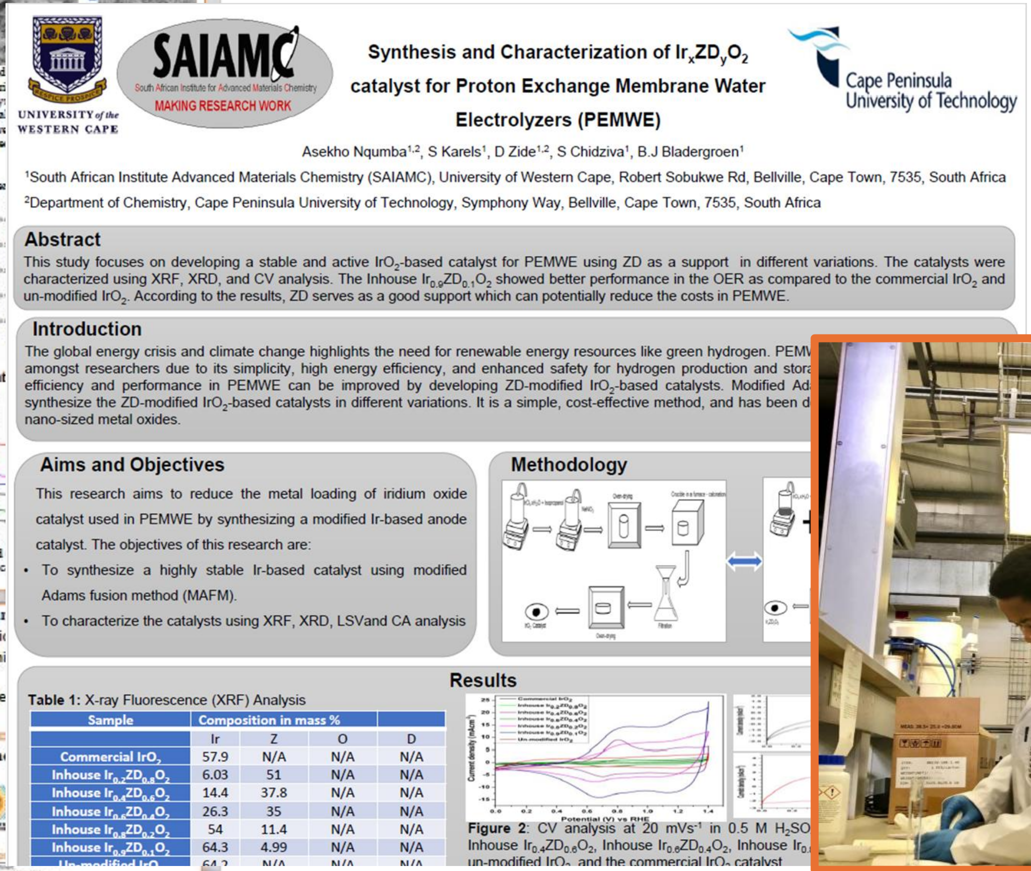
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Synthesis and Characterization of $Ir_xZD_yO_2$ catalyst for Proton Exchange Membrane Water Electrolyzers (PEMWE)
Cape Peninsula University of Technology
Asekho Nqumba1,2, S Karels1, D Zide1,2, S Chidziva1, B.J Bladergroen1
1South African Institute Advanced Materials Chemistry (SAIAMC), University of Western Cape, Robert Sobukwe Rd, Bellville, Cape Town, 7535, South Africa
2Department of Chemistry, Cape Peninsula University of Technology, Symphony Way, Bellville, Cape Town, 7535, South Africa
Abstract
This study focuses on developing a stable and active IrO_2-based catalyst for PEMWE using ZD as a support in different variations. The catalysts were characterized using XRF, XRD, and CV analysis. The Inhouse $Ir_{0.9}ZD_{0.1}O_2$ showed better performance in the OER as compared to the commercial IrO_2 and un-modified IrO_2. According to the results, ZD serves as a good support which can potentially reduce the costs in PEMWE.
Introduction
Aims and Objectives
This research aims to reduce the metal loading of iridium oxide catalyst used in PEMWE by synthesizing a modified Ir-based anode catalyst. The objectives of this research are:
To synthesize a highly stable Ir-based catalyst using modified Adams fusion method (MAFM).
To characterize the catalysts using XRF, XRD, LSVand CA analysis
Methodology
Results
Table 1: X-ray Fluorescence (XRF) Analysis
Sample | Composition in mass %
Ir | Z | O | D
Commercial IrO_2 | 57.9 | N/A | N/A | N/A
Inhouse $Ir_{0.1}ZD_{0.9}O_2$ | 6.03 | 51 | N/A | N/A
Inhouse $Ir_{0.2}ZD_{0.8}O_2$ | 14.4 | 37.8 | N/A | N/A
Inhouse $Ir_{0.4}ZD_{0.6}O_2$ | 26.3 | 35 | N/A | N/A
Inhouse $Ir_{0.6}ZD_{0.4}O_2$ | 54 | 11.4 | N/A | N/A
Inhouse $Ir_{0.9}ZD_{0.1}O_2$ | 64.3 | 4.99 | N/A | N/A
Figure 2: CV analysis at 20 mVs-1 in 0.5 M

Green Hydrogen Educational Kit Demonstration

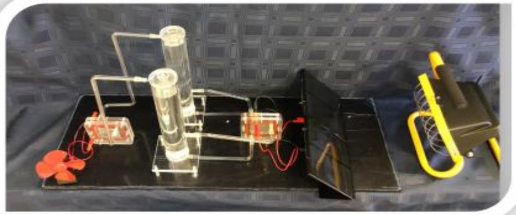
A green hydrogen demonstration kit is an educational tool designed to illustrate the principles and technologies behind the production and use of green hydrogen. The kits are often used in schools, universities, and industry training programs to provide hands-on experience with hydrogen technology.

Educational Kit Objectives

- Understanding Electrolysis
- Renewable Energy Integration
- Fuel Cell Operation
- Energy Storage and Conversion
- Safety Practices

Demonstration kit model includes:

- PEM Electrolyser
- Water Tanks
- PEM Fuel Cell
- Solar Module
- Electric load fan



Benefits of Using a Green Hydrogen Demonstration Kit

- Hands-On Learning
- Visual and Tangible
- Encourages STEM Education
- Real-World Applications

OUTPUTS

Technical data

Electrolyser

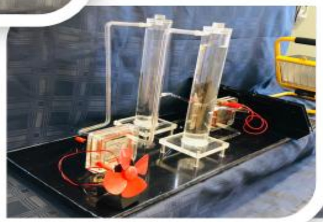
- Current: 0-5A
- Voltage: 0-2.0V DC
- Distilled water conductivity: < 2 μS/cm

Fuel Cell

- Power Output: 1.2W
- Open circuit voltage: 1V DC

Accessories

- Water reservoir: Approx. 500 mL
- Solar module: 2.0V/1.0A
- Load (Fan): 10 mW



Summary

A green hydrogen demonstration kit is a valuable educational tool that helps students and enthusiasts understand the principles and applications of green hydrogen technology. By providing hands-on experience, these kits can inspire the next generation of scientists, engineers, and innovators in the field of sustainable energy

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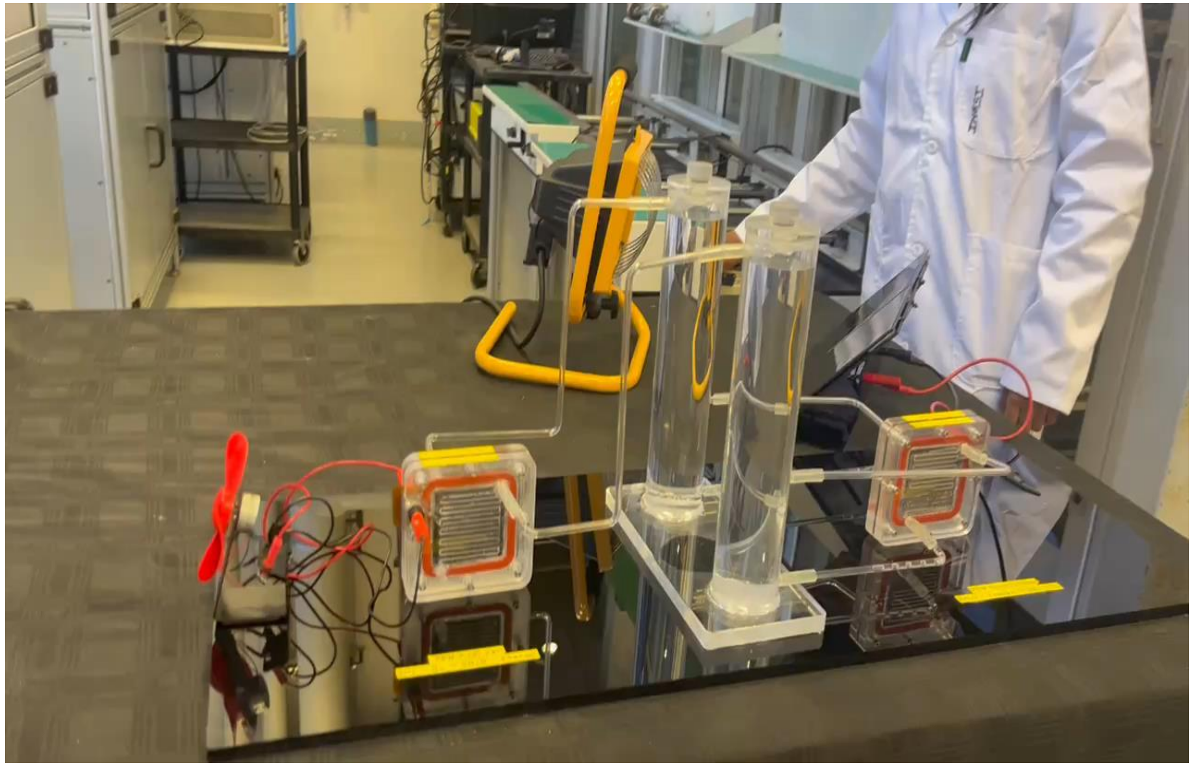

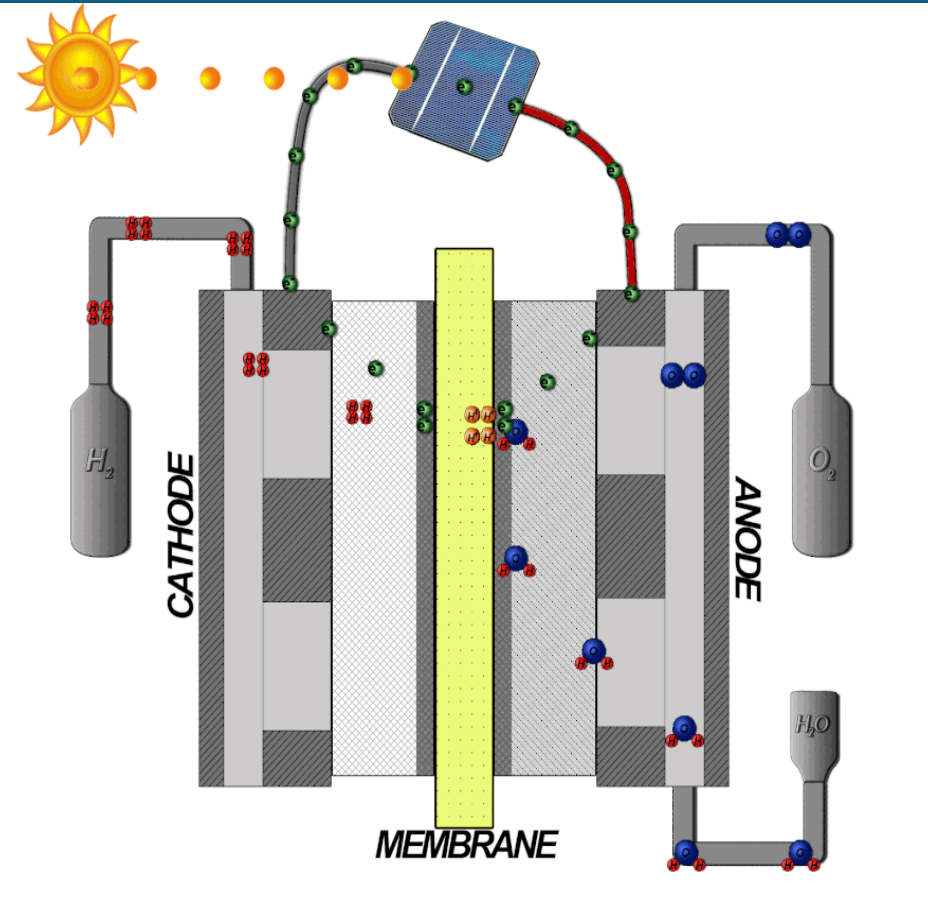

Thank you