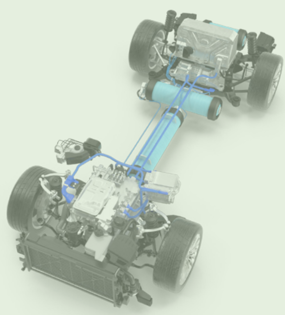
2ND SOUTHERN AFRICAN HYDROGEN AND FUEL CELL CONFERENCE 2025

7-8 APRIL 2025

SOUTHERN SUN ROSEBANK, JOHANNESBURG

Pathway to industrialisation



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THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY
130 Years OF TECHNICAL EXCELLENCE

THE SOUTHERN AFRICAN INSTITUTE OF MINING AND METALLURGY JOHANNESBURG 2025

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FOREWORD

The primary purpose of the 2ND Hydrogen and Fuel Cells conference is the advancement of green hydrogen technologies in Southern Africa and the global community, by highlighting the power of renewable and sustainable technologies and addressing the emerging challenges—through the exploration of hydrogen production, storage and utilization using fuel cells by way of engagement with industry, academia and government. The conference will provide a platform for high level exchange and networking opportunities with various experts in the field. The two-day conference will feature high-level scientific talks and posters, complemented with keynote and plenary presentations on country overviews, status of leading and major players in the Southern African and global arena.

B.S. Xakalashe
Conference Chairperson

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Conference Chairperson

Buhle Sinaye Xakalashe

Mintek

Buhle has over 15 years of research and development experience in the field of extractive metallurgy from the following local and global institutions: Mintek (South Africa), NTNU/SINTEF (Norway), RWTH Aachen University (Germany), KU Leuven (Belgium) and the National Technical University of Athens (NTUA) (Greece). He has industrial experience through a stint at TRONOX Namakwa Sands' DC arc furnace operation for the production of high TiO2 slag and pig iron. Buhle is currently the Head of New Technology in the Pyrometallurgy Division at Mintek. He is a member of the Technical Programme; Diversity and Inclusion in the Minerals Industry (DIMI); Environmental, Social, Governance and Sustainability (ESGS) committees of the Southern African Institute of Mining and Metallurgy (SAIMM). He contributes to organising of conferences including but not limited to the Furnace Tapping Conference 2014, Mine-Impacted Water Conferences (2020 & 2022), Southern African Rare Earths International Conference 2021 and the 8th International PGM Conference 2022. Buhle is passionate about batteries, particularly battery recycling towards a circular economy.

Keynote Presenters

Mandy Mlilo

Acting Chief Director: Hydrogen and Energy
Department of Science, Technology and Innovation

Ms Mandy Mlilo currently holds the Acting Chief Director: Hydrogen and Energy position in the Department of Science, Technology and Innovation. The purpose of the position is to stimulate, develop and entrench a culture of innovation within the South African energy sector by contributing towards development and implementation of policies and relevant instruments, platforms and programmes that inspire, require and foster interaction and innovation among all the stakeholders in the knowledge value chain within the energy space.

Ms Mlilo also has five years' experience in process control and operations of mineral processing and pyrometallurgical pilot plants as well as five years' experience in a nuclear environment. One of her recent key achievements include:

- Being part of the core team from the Department of Science, Technology and Innovation that led to the Cabinet approval of the Inter-Ministerial Committee on Hydrogen Economy on 14 February 2024, to be chaired by the Deputy President, aimed at improving coordination and alignment, particularly across the public sector on the implementation of the Hydrogen Society Roadmap, Green Hydrogen Commercialisation Strategy and other hydrogen economy-related policies and strategies.
- Being part of the core team from the Department of Science, Technology and Innovation that led the development of the Hydrogen Society Roadmap, which was approved by Cabinet on 14 September 2021. The Cabinet also approved the ten years extension of the Hydrogen South Africa (HySA) Programme, from 2022/23 financial year (FY) up to 2030/31 FY.

Professor Lindiwe Khotseng

University of the Western

Lindiwe Khotseng joined the Chemistry Department at the University of the Western Cape, South Africa, in 2015, where she currently holds the position of Professor. Before this role, she served as the Managing Director of the ESKOM Centre for Electrocatalytic Research at the South African Institute for Materials Research, also at the University of the Western Cape, from 2008. Lindiwe earned her PhD in Chemistry from Stellenbosch University in 2004 and a Postgraduate Diploma in Teaching and Learning in Higher Education from the University of the Western Cape in 2022. Her research focuses on biomass and waste valorisation for sustainable renewable energy applications within the circular economy framework. Lindiwe is an accomplished scholar who has published extensively in peer-reviewed international journals and contributed to specialised books. She has presented her work at numerous international conferences. As a mentor and educator, she has successfully supervised multiple MSc and PhD students, fostering the next generation of scientists in her field. Lindiwe has played an active role in academic leadership, serving on various faculty committees and National Research Foundation (NRF) panels in South Africa. Her contributions to the scientific community were recognised in 2013 when she received the Department of Trade and Industry's Technology Award for Outstanding Black Researcher in her field. Lindiwe is a professional member of several organisations, including the South African Chemical Institute (SACI), the Organization for Women in Science for the Developing World (OWSD), and the International Society of Electrochemistry (ISE).

Francois van Schalkwyk

Key Technology Specialist: Fuel Cells
University of Cape Town; HySA Catalysis

Francois is a Chemical Engineer by profession and has more than 12 years of experience in the hydrogen industry, specialising in electrochemical sub-components (Membrane Electrode Assemblies), material design, product development and process engineering. He is a co-inventor of several catalyst and -MEA technologies emanating from the HySA Catalysis program and HyPlat. His career started at the South African Council for Mineral Technologies (Mintek), where he contributed to HySA Catalysis' fuel cell objectives as Research Engineer. Thereafter he joined HyPlat, where he directed operations, MEA manufacturing, quality control and product development – making him the lead technical contact for the company. Francois is currently focussing on research and technology development of fuel cell technologies at the University of Cape as Key Technology Specialist and head of the FC group. He is a Six Sigma Black Belt improvement practitioner, holds an MSc in Chemical Engineering from the University of Cape Town (UCT) and is currently working towards his doctorate degree in the same engineering discipline.

Pathways to reduce costs and improve efficiency for scaling hydrogen and fuel cell technologies

L. Khotseng
University of Cape Town, South Africa

Hydrogen and fuel cell technologies hold significant potential for advancing clean energy solutions, but their widespread adoption is hindered by high costs and efficiency challenges. There are various key pathways to reduce costs and improve efficiency for scaling these technologies. These strategies include enhancing hydrogen production through advanced electrolysis, exploring alternative production methods such as biomass gasification and methane pyrolysis. Improvements in fuel cell efficiency can be achieved by developing non-precious metal and modified Pt catalysts, improving membrane durability, and optimising system design. Additionally, innovations in hydrogen storage and distribution—such as high-density storage materials, liquid organic hydrogen carriers, and expanded infrastructure—are critical for cost reduction. By addressing these key challenges, hydrogen and fuel cell technologies can become more viable, cost-effective, and widely deployed in the global transition to clean energy. I will present some of the work that has been done in these areas to contribute to the realisation of hydrogen and fuel cell technologies.

Advanced electrocatalysis for green hydrogen production

Z.S.H.S. Rajan, G. Moss, J. Itota, D. Susac, R. Mohamed
University of Cape Town, South Africa

Summary
Proton exchange membrane water electrolysis (PEMWE) plays a crucial role in green hydrogen production from renewable sources. One significant barrier to the commercial use of PEMWE is the slow kinetics of the oxygen evolution reaction at the anode, necessitating high-cost, low-abundance PGM-based electrocatalysts. This abstract discusses novel synthesis strategies for high-performance iridium-based electrocatalysts developed at the Catalysis Institute at the University of Cape Town.

Introduction
Iridium-based oxides, known for their high oxygen evolution reaction (OER) activity and corrosion stability, are currently the most feasible option for PEMWE technologies. However, future advancements depend on reducing costs and enhancing corrosion resistance of critical components like the anode catalyst, the catalyst-coated membrane, and the porous transport layer. Research at the Catalysis Institute aims to develop corrosion-resistant electrocatalysts with enhanced OER performance and iridium utilisation.[1] Conventional synthesis routes usually necessitate high-temperature processes for oxidation and crystallisation, which unfortunately result in particle enlargement and diminished active surface area. Our studies have identified the thermodynamic instability of the oxygen anion in metal oxides under OER conditions as a key factor driving corrosion, termed the lattice oxygen evolution reaction.[2] This insight has guided the development of novel electrocatalysts using an in-house developed metal-organic chemical deposition method, showing superior OER performance with small, highly dispersed rutile iridium dioxide (IrO2) nanoparticles epitaxially anchored on antimony-doped tin oxide supports [3,4]. Additionally, an innovative synthesis approach that maximises the unique qualities of crystalline IrO2 has also been developed in-house. This novel perchlorate fusion hydrothermal treatment method operates at low temperatures to produce small IrO2 nanoparticles (approximately 2 nm) with high crystallinity [5]. This catalyst shows a high mass-specific OER activity and remarkable durability under rigorous accelerated stress tests. These findings highlight the efficacy of our tailored synthesis approaches in maximising the inherent properties of nano-crystalline IrO2 electrocatalysts, effectively addressing the usual trade-offs between OER activity and catalyst stability.

Keywords: electrocatalysis, renewable energy, hydrogen generation, PEM water electrolysis, electrocatalysts

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Ziba S.H.S. Rajan

Senior Scientific Officer – PEM Electrolysis Technology
University of Cape Town (HySA Catalysis)

Ziba is a dedicated researcher and chemical engineer specialising in the development of cost-effective and robust materials for hydrogen generation through proton exchange membrane water electrolyser (PEMWE) technologies. Her expertise lies in engineering innovative catalysts with low precious metal content, an interest that she developed during her MSc. studies. Over the past seven years, Ziba has been a key contributor to the PEMWE technology development initiatives at HySA/Catalysis, a centre of competence co-hosted by the University of Cape Town and MINTEK, where she currently holds the role of Senior Scientific Officer. This centre is part of South Africa's Hydrogen South Africa (HySA) program, which aims to support the country's hydrogen roadmap by fostering scientific research and innovation.

HySA/Catalysis focuses on advancing catalyst and membrane electrode assembly technologies for hydrogen production and utilisation. Ziba's work is instrumental in supporting these efforts, contributing to both national energy goals and global advancements in sustainable hydrogen technologies. Ziba's contributions have included developing PEMWE catalyst and electrode prototypes, knowledge application products, publishing these findings in internationally peer-reviewed publications, and representing the group at several international conferences.

In addition to her technical interests, Ziba is highly passionate about enhancing the accessibility of high-quality scientific education in developing countries, and empowering women in scientific careers.

Locally developed test station for water electrolysis characterisation with advanced capabilities

A.S. Pushkarev, I.V. Pushkareva, C. Martinson, S. Mamathuntsha, H. Brink, S. Modise, A. Malakhov, D. Bessarabov
North-West University, South Africa

The transition to sustainable energy requires efficient, cheap, and reliable solutions for producing green hydrogen. Proton exchange membrane (PEM) water electrolysis is the key technology for getting green hydrogen from renewable energy sources, but its widespread adoption is hindered by challenges related to cost, durability, and the usage of platinum group metals. To foster the innovation in materials and cell/stack design, advanced approaches for 'in situ' and 'ex situ' characterisation of the cell itself or its components in realistic conditions are necessary.

There is an acknowledged need for objective comparative assessment of the behaviour of electrolyser components and devices under conditions foreseen in future applications, so harmonised approaches on testing protocols were delivered [1]. According to them, to unpack the PEM water electrolyser losses breakdown, a test station with wide in situ testing capabilities is necessary. Moreover, there are various mechanisms of PEM water electrolyser cell degradation – depending on certain of its components and the strategy of its fabrication – which often combine, making it very difficult to access certain mechanisms. Fundamental understanding of electrolyser degradation is essential to reach the lifespan targets set to >80 000 h by the Department of Energy[2].

To address these challenges, an advanced test station was designed and manufactured. Its capabilities include independent anode and cathode loop, accurate test cell temperature management, feeding water quality management, H2/N2 mode operation, in situ cross-over measurements, and electrochemical impedance spectroscopy measurements at high current densities.

In this paper we share the current progress on its development and usage, as well as describe and discuss the value of PEM water electrolyser development.

G. Tsotridis, A. Pilenga, EU harmonised protocols for testing of low temperature water electrolysers, Westerduinweg, The Netherlands, 2021. https://doi.org/10.2760/58880

U.S. Department of Energy (DOE), Technical Targets for Proton Exchange Membrane Electrolysis, https://www.energy.gov/eere/fuelcells/technical-targets-proton-exchange-membrane-electrolysis (accessed on 28th of January 2025).

Artem Pushkarev
Postdoctoral Fellow
HySA Infrastructure Centre of Competence, North-West University

I was graduated from the National Research University "Moscow Power Engineering Institute (MPEI)", Moscow, receiving my Ph.D. degree in electrochemistry in 2019. In 2012–2023 I was working in National Research Centre "Kurchatov institute" and ended up as a Senior Researcher. I was performing an R&D of electrochemical technologies based on ion exchange membranes, i.e., fuel cells, water electrolyzers, and hydrogen and oxygen concentrators. In 2020–2023, I was also involved in teaching activities as a Senior Lecturer in MPEI. In 2021 I have a 6-month trainee in ISE Fraunhofer, Germany, focused on the application of Electrochemical impedance spectroscopy to water electrolysis characterization. Currently, I am a Postdoctoral Fellow in HySA Infrastructure Centre of Competence, North-West University, South Africa. My research is focused on the advanced electrochemical characterization of PEM water electrolyzers and development of its components including catalysts, electrodes, and membrane electrode assemblies.

Investigations of oxygen evolution reaction catalysts for proton exchange membrane water electrolyser

M. Kozlova[1,2], I. Pushkareva[3], D. Bessarabov[3], A. Pushkarev[3]
[1]National Research Center "Kurchatov Institute", Russia
[2]National Research University "Moscow Power Engineering Institute", Russia
[3]HySA Infrastructure Centre of Competence, North-West University, South Africa

The development of renewable energy sources increases rapidly to accelerate the energy transition to global carbon neutrality; hence, the capacity of green energy transport and storage is to be established. Due to its high-energy content and environmentally friendly combustion products (its reaction with oxygen to generate electricity produces only water), hydrogen is a promising energy carrier for that purpose. Proton exchange membrane water electrolyser (PEMWE) is among the key technologies for obtaining green hydrogen.

Oxygen evolution reaction (OER) is a key process that determines the overall efficiency of electrochemical water splitting [1]. An ideal OER catalyst must have sufficient activity for the reaction to proceed efficiently, while maintaining long-term stability to avoid rapid degradation or loss of performance. Achieving this balance is a key to improving the overall performance and efficiency of water electrolysers, which depend on the performance of OER catalysts. The most efficient OER catalysts to date are Ir and Ru-based electrocatalysts, as they have excellent stability in acidic media. Their oxides, such as RuO_2 and IrO_2, are considered as advanced OER catalysts [2].

Although RuO_2 has higher OER activity, it is inherently unstable during the reaction, making it unsuitable for long-term industrial use. In this regard, Ir-based catalysts are considered as the only feasible option due to their outstanding balance between catalytic activity and stability. However, iridium is characterised by a high cost due to the extremely low reserves of this element (even ten times lower than platinum). Therefore, increasing the efficiency of Ir utilisation and reducing its content at the anode has become a key challenge on the way to the widespread application of PEMWE [3].

In this study, OER catalysts such as Ir nanoparticles and Ir-black will be prepared by various methods and characterised. The effect of particle morphology and structure on their performance and durability will be discussed. This integrated approach will provide an understanding of the key factors affecting catalyst performance, which will provide the basis for their future use in PEMWE membrane-electrode assemblies.

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Margarita Kozlova

PhD student (exchange PhD student)
National Research University "Moscow Power Engineering Institute" (exchange PhD student at HySA Infrastructure Center of Competence)

Margarita Kozlova is a researcher specializing in green hydrogen technologies. She is currently pursuing a PhD at the National Research University 'Moscow Power Engineering Institute' and working as a researcher at the National Research Centre 'Kurchatov Institute.' She has published nine scientific papers in international peer-reviewed journals.

She completed her undergraduate studies (2015–2019) at the National Research University 'Moscow Power Engineering Institute,' focusing on sodium-ion batteries. During her master's program (2019–2021), she shifted to green hydrogen technologies, which remain her research focus in her ongoing PhD program. In 2021, she received the Kurchatov Award for the Best Young Scientist.

In 2024, she was awarded the Presidential Scholarship of the Russian Federation for studying abroad and is currently completing a research internship at the HySA Infrastructure Center of Competence at North-West University, South Africa.

She also has international academic experience, having participated in an educational program at the Beijing Institute of Technology in 2023.

A computational approach to designing high entropy alloys for hydrogen storage

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The advancement of effective and sustainable hydrogen storage technology is essential for the hydrogen economy. High-entropy alloys (HEAs) have emerged as attractive materials owing to their unique structural characteristics, thermal stability, and customisable hydrogen absorption/desorption kinetics. This paper employs a computational methodology to build HEA-based metal hydrides, employing advanced programs such as HEAPS, Thermo-Calc, and Model MH to optimise alloy composition and microstructure. We examine the interaction between body-centred cubic (BCC) alloys and Laves-phase intermetallics to improve hydrogen storage capacity, phase stability, and performance using a computational approach. Our research offers significant insights into the importance of valence electron concentration (VEC), phase engineering, and thermodynamic modelling in the design of HEAs. These computational improvements facilitate the creation of next-generation hydrogen storage materials, which have substantial implications for fuel cell applications, especially in the transportation and renewable energy sectors.

Keywords: hydrogen storage, high-entropy alloys, metal hydrides, computational modelling, fuel cell applications, clean energy.

Ramatsoma Bongani Seeke

Assistant Lecturer
University of Johannesburg

Mr Ramatsoma BS is an Assistant Lecturer in the Department of Metallurgy at the University of Johannesburg, specializing in materials science and hydrogen storage technologies. Currently pursuing a PhD, their research focuses on high entropy alloy (HEA) metal hydrides as a novel solution for hydrogen storage. By exploring the thermodynamic, structural, and kinetic properties of these materials, He aims to enhance their performance in terms of storage density, reversibility, and stability, contributing to the advancement of sustainable hydrogen storage technologies for clean energy applications.

As an educator, Mr Ramatsoma teaches undergraduate courses in materials science at UJ. They are dedicated to mentoring the next generation of engineers and materials scientists by blending theoretical knowledge with practical, hands-on learning. Through their work, Mr. Ramatsoma is helping to aims to development of efficient, sustainable energy solutions and contribute to the global transition to clean energy.

Optimization of metal hydride tanks for hydrogen storage through heat and mass transfer modelling

B.L. Hem, A. Kolesnikov
Tshwane University of Technology, South Africa

The research for this paper on metal hydride (MH) tanks was done to identify design parameters for optimization of hydrogen storage. The main objective was to develop an equation that could be used to calculate the desired hydrogen charge rate and discharge rate as a function of the reactor's dimensions, inlet conditions, and boundary conditions. This was accomplished with the aid of a semi-empirical formula that was created from a collection of experimental data. COMSOL software was used to simulate the heat and mass transfer in the hydrogen storage tank and produce experimental data. Simulations for several MH tank geometries with various boundary conditions were performed, and the charge/discharge rates were predicted, as well as the time to achieve 90% of the maximum H_2 capacity. A two-dimensional model of heat and mass transfer in a MH tank for hydrogen storage was developed as a set of partial differential equations. These partial differential equations describe spatial (in space) and temporal (in time) variations of temperature, pressure, velocity, and hydrogen concentration in the volume of the tank and MH particles. Analytical solutions are not possible due to the strong nonlinearity of these equations; hence numerical methods must be used; therefore, COMSOL software was selected to perform simulations. The model was used to run independent simulations for absorption and desorption for various boundary conditions. Via simulations, the effects of the tank parameters such as length, number of plates and spacing between plates inside the MH tank in the hydrogen absorption processes employing $LaNi_5$ alloy were investigated.

Bongiwe Ladyfair Hem

Process engineer in Training
Tshwane university of Technology

Bongiwe Ladyfair Hem is a dynamic and results-driven process engineer in training, passionate about innovation, sustainability, and strategic problem-solving in industrial operations. Currently with Idwala Industrial Holdings, as a process engineer in training where she specializes in process optimization, energy efficiency, and the implementation of eco-friendly solutions in mining and chemical engineering. She is a registered Candidate Engineer with the Engineering Council of South Africa (ECSA) and an Associate Member of the Southern African Institute of Mining and Metallurgy (SAIMM).

Bongiwe holds a Master of Engineering (MEng) in Chemical Engineering from Tshwane University of Technology, where her research focused on optimization of hydrogen storage using COMSOL modelling software. Additionally, she explored simulation and problem-solving using AnyLogic, integrating system dynamics, discrete event modelling, and agent-based approaches to develop dynamic business models that enhance operational efficiency and sustainability in industrial processes.

Her professional experience spans industrial operations, research, and academia. She has worked on diverse projects, including process optimization in mining operations, water and wastewater treatment, and the integration of sustainable practices. As a researcher at the Council for Scientific and Industrial Research (CSIR), she was involved in forward osmosis, reverse osmosis, and membrane distillation technologies to treat acid mine drainage and brine, contributing to water conservation and resource recovery initiatives.

In her current role, Bongiwe is responsible for monitoring plant processes, conducting energy and material balance analyses, and supporting the implementation of process modifications and technology trials to enhance efficiency. She actively collaborates with cross-functional teams, ensuring compliance with environmental regulations and safety standards while driving continuous improvement in operational performance.

Beyond her technical expertise, Bongiwe has a strong academic background, having spent over two years mentoring and supervising chemical engineering students. She has experience in practical training, tutoring, and guiding students through experimental work and industry-related projects. This has strengthened her leadership skills and ability to communicate complex engineering concepts effectively.

Bongiwe is eager to further develop her expertise in sustainable mining practices, hydrogen technologies, and energy transition strategies to contribute to a greener future. She aims to bridge the gap between research and industry by applying innovative solutions to real-world challenges in mining and process engineering.

Her unique blend of technical expertise, research-based perspectives, and strategic leadership positions her as a significant force in promoting sustainable industrial practices. She is still dedicated to using teamwork, creativity, and lifelong learning to create significant change as she pursues her engineering career.

Design and development of metal hydride hydrogen compressors at HYSA systems based at the University of the Western Cape

M.W. Davids, M. Lototskyy, V. Linkov, S. Pasupathi
University of Cape Town, South Africa

Considering the global energy scenario and the significant increase in CO2 concentration in the atmosphere, there is a need to shift towards a hydrogen-based economy to meet future energy demands without harming the environment. One of the main problems facing the widespread introduction of the hydrogen economy is hydrogen storage and compression. Metal hydrides have emerged as a promising class of materials for hydrogen storage and compression application. Hydrogen compression has a significant share in the capital costs and maintenance efforts to enable the operation of the infrastructure related to the storage, distribution and end-use of hydrogen. Conventionally used mechanical hydrogen compressors have several disadvantages, including a complicated design, insufficient reliability, high operational costs, while facing challenges in avoiding hydrogen leakage and hydrogen contamination. A promising alternative to compressing hydrogen gas is thermally driven metal hydride hydrogen compressor (MHHC). Its operation is based on a reversible formation-decomposition of metal hydrides when the hydride-forming alloys interact with hydrogen gas. The advantages of MHHC include simplicity in design and operation, absence of moving parts, compactness, safety and reliability, and the possibility to consume waste industrial heat instead of electricity.

HySA Systems, based at the University of the Western Cape, has successfully designed and developed several pre-industrial scale MHHCs capable of compressing hydrogen from 5 bar to 200 bar using low-grade steam input ranging ∼ 1500C; recently, the company has developed a prototype MHHC capable of compressing hydrogen from 100 bar to 700 bars.

This presentation reviews research, development, and innovation activities in South Africa in the field of metal hydride compressors and related technologies; mainly considering the work performed at the HySA Systems Centre of Competence hosted by SAIAMC / UWC.

Keywords: metal hydrides, metal hydride compressor, hydrogen compression

Moegamat Wafeeq Davids

Key Technology Specialist (hydrogen technology)
HySA Systems / University of the Western Cape

I completed my PhD in 2012 at the UWC, working on hydrogen storage materials focusing primarily on the surface chemistry of these materials. Upon completion of my PhD, I pursued a post-doctoral research fellowship (2013-2017) at HySA systems, working on synthesizing metal hydride alloys, system integration of hydrogen storage tanks coupled with PEMFC stacks, and developing metal hydride compressors. Presently, I am employed as a Key Technology Specialist on hydrogen technology-related applications at the South African Institute for Advanced Materials Chemistry (SAIAMC) within the South African Hydrogen and Fuel Cell Technologies RDI Program (HySA Systems Competence Centre hosted by UWC). I'm involved in the planning and managing of hydrogen storage and hydrogen fuel cell system integration-related research and supervision of postgraduate students and lecturing.

Application of hydrogen as a reductant in metal production: Modelling and experimentation

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Metal production is generally carried out using carbon-based reductants in furnaces. A typical example is the production of ferroalloys; predominantly undertaken through carbothermic reduction in electric arc furnaces. Conventional reductants constitute fossil carbon and this renders metal production carbon dioxide emissions intensive. Reductants such as hydrogen, where water is the only by-product, have become attractive potential alternatives for metal production in addressing the high greenhouse gas emissions. Unlike the carbon-based metal production processes, hydrogen-based metal production processes have not achieved widespread application in industry. They are at various technology readiness levels, thus requiring further research and development. The use of hydrogen in metal production is based on pre-reduction, direct-reduction and plasma smelting with hydrogen. As a basis for designing hydrogen-based metal production processes, it is crucial to carry out comprehensive studies based on a combination of modelling and experimentation (laboratory and pilot scale) towards industrial applications. This contribution focuses on computational fluid dynamics studies on solid-state pre-reduction of manganese ore with hydrogen, experimental studies on the kinetics of pre-reduction of chromite concentrate with hydrogen, and a pilot scale pre-reduction of manganese with hydrogen. Furthermore, computational multiphysics modelling for the production of metals using hydrogen in direct-current smelting furnaces.

Keywords: hydrogen, pre-reduction, smelting

Mopeli Khama

Senior Engineer
Mintek

Mopeli Khama holds a PhD in chemical engineering from the University of Kwazulu Natal. His PhD work focused on the development of computationally efficient CFD-Hybrid models for heterogeneous systems. He has also worked on Population Balance modelling of bubble column reactors during his MSc studies at the University of Cape Town. His current research interests are in the Computational Fluid Dynamics model development and analysis of gas-solid pre-reduction processes with the view to aid design and optimization. These CFD models will help the de-carbonization initiatives in the metal production processes.

Investigation of Pt ternary alloy catalysts as PEMFC ORR catalysts

Z. Mseleku, T. Ngwenya, K. Tshehla, C. Gray
Mintek, South Africa

The slow kinetics of the cathodic oxygen reduction reaction (ORR) poses a challenge in the industrialisation of PEMFCs. Additionally, high Pt content is required to overcome the large overpotential of the ORR, resulting in high cost of the catalysts required. To mitigate this, the Pt content can be reduced while improving the ORR activity by alloying Pt with transition metals, which results in a downshift of the Pt d-band and weakens the Pt-O bond. This work investigated synthesising Pt ternary alloy catalysts with low Pt content and testing the activity towards ORR. Pt- M_1-M_2/C catalysts with a Pt content of 20 wt% (where M_1 and M_2 are combinations of Co, Cu and Ni) were synthesised via an aqueous deposition chemical reduction method. Characterisation via XRD analysis showed that the Pt alloy crystallite size was between 3 and 5 nm, which concurs with the theoretical Pt desorption crystallite size from TF-RDE measurements. A slight shift of the XRD peaks to higher 2θ values indicated successful alloying of Pt with base metals. The preliminary TF-RDE results showed a slight improvement in the ORR activity and stability of the Pt ternary alloy catalysts compared to the commercial Platalite-K40 (Pt/C) catalyst.

Synthesis, characterisation and testing of ruthenium-modified iridium oxide ($IrxRuyO_2$) catalyst in a laboratory scale proton exchange membrane water electrolysers (PEMWE)

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The development of highly stable and efficient catalysts for proton exchange membrane water electrolyzers (PEMWE) is crucial for advancing the oxygen evolution reaction (OER). IrO_2 is a widely used catalyst due to its stability; however, its high cost necessitates the exploration of alternative or modified materials to improve cost-effectiveness. This study successfully synthesized Ru-modified IrO_2 and unsupported IrO_2 via the Adams Fusion Method. The synthesized catalysts were characterized using XRD and SEM to analyze their elemental composition, crystal structure, and morphology. Electrochemical performance was evaluated through CV, LSV, and chronoamperometry (CA) to assess OER activity and durability. Furthermore, the study assessed the membrane electrode assembly (MEA) performance of synthesized $Ir_{0·7}Ru_{0·3}O_2$ electrocatalysts for PEMWE. The $Ir_{0·7}Ru_{0·3}O_2$ catalyst exhibited superior catalytic activity compared to commercial IrO_2, suggesting that incorporating Ru enhances OER performance while reducing catalyst costs. Additionally, the in-house catalyst-coated membranes outperformed commercial alternatives, highlighting their potential for PEM electrolyzers. The $Ir_{0·7}Ru_{0·3}O_2$ demonstrated excellent electrochemical performance, offering a cost-effective alternative for green hydrogen production. MEA testing confirmed that synthesized $Ir_{0·7}Ru_{0·3}O_2$ outperformed commercial catalysts in terms of current density and overall efficiency, highlighting its potential for sustainable hydrogen production.

Keywords: Electrocatalysis; Oxygen evolution reaction (OER); Proton exchange membrane water electrolyzers (PEMWE); Iridium oxide-based catalystIntroduction

Dorcas Zide

Lecturer/ Affiliated Researcher at SAIAMC-UWC
Cape Peninsula University of Technology

Dr. Dorcas Zide is an Analytical Chemist with a strong background in both academia and industry. She earned her PhD from the Cape Peninsula University of Technology (CPUT) in collaboration with the South African Institute for Advanced Materials Chemistry (SAIAMC) at the University of the Western Cape (UWC). Currently a Lecturer at CPUT, she plays a vital role in educating and mentoring future scientists, having previously served as a Chemistry Facilitator and Retention Officer. She is also an Affiliated Researcher at SAIAMC.

Dr. Zide's career extends beyond academia, with significant contributions to industry initiatives. She has worked with PPC Cement, Wesgro, and the Transfer and Industrial Linkages Office (TTO), where she engaged in technology transfer and industrial partnerships. Her expertise spans sustainable energy technologies, including NiFe and Li-ion battery production, membrane capacitive deionization (MCDI), zeolites, nanomaterials, and applied catalysis.

A passionate advocate for sustainability and innovation, Dr. Zide leads research projects tackling environmental challenges. She supervises MSc and PhD students, as well as Work Integrated Learners (WILs), guiding them in critical research areas such as water desalination, green hydrogen production, and electronic waste management - particularly recycling valuable metals from used Li-ion batteries. Her dedication to mentorship was highlighted in 2023 when two of her WIL students secured 1st and 3rd place at the CPUT Chemistry Mini-Symposium Science Idols competition on November 22.

Beyond research and teaching, Dr. Zide actively contributes to international collaborations. She voluntarily serves as the Climate, Energy, and Mobility South African Assistant National Contact Point (ANCP) for the Horizon Europe Framework under the Department of Science and Innovation (DSI). In this role, she facilitates scientific cooperation between South Africa and European researchers. Additionally, she is a trainer for the Green Hydrogen Power to X Training for Decision Makers Workshops, a program led by UWC and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, aimed at promoting the adoption of green hydrogen technologies.

Development progress of high-performance, durable and low-cost fuel cell MEA solutions at HySA catalysis (UCT)

F. van Schalkwyk, D. Susac
University of Cape Town, South Africa

It is well established that a shift is necessary in the global energy system from the current system which is overwhelmingly rooted in fossil fuels. Renewable energy is a viable route to meet global energy needs and green hydrogen (GH2) has become the foremost cited vector to unlock its potential sustainability. Water electrolysis is currently the leading technology for commercial GH2 production. In turn, that hydrogen can then be converted into other green molecules or stored, transported, and used on demand in hydrogen-fuelled fuel cells to provide emission-free power. For South Africa in particular, the hydrogen economy offers a pathway to a sustainable future. The country's rich endowment of ideal weather conditions for renewable power generation, its wealth of platinum group metal resources and its long-standing investment in electro-chemical hydrogen conversion technologies places the country in an ideal position to develop the hydrogen value chain, being a key supplier into the global hydrogen market and ultimately catalyse a just and equitable shift from a resource-based economy to a knowledge-based economy. The South African government identified this opportunity and in 2008 embarked on the National Hydrogen and Fuel Cells Technologies Flagship project, branded as Hydrogen South Africa (HySA). From the HySA Catalysis Centre of Competence, co-hosted by the University of Cape Town (UCT) and the South African Council for Mineral Technologies (Mintek), emanated pivotal hydrogen conversion technologies in the fields of fuel cell catalysts and membrane electrode assembly (MEA) manufacturing, which have been commercialised through, and expanded on by HyPlat since 2014. This paper will introduce research and development progress on HySA Catalysis' efforts aimed at addressing technical and commercialisation requirements of proton exchange membrane fuel cell MEAs and the associated manufacturing technologies. Research highlights including achievements in the development of MEAs with reduced fluorine and platinum content, improved cell reversal tolerance and reduced inhomogeneities (defects) will be discussed.

Roll-to-roll coating methods for the manufacture of PEMFC MEAs

C. Felix, O. Barron
Mintek, South Africa

In 2023, polymer electrolyte membrane fuel cell (PEMFC) membrane electrode assemblies (MEAs) accounted for about 62% of the global fuel cell market share and this demand is expected to grow. Commercialisation requires technologies capable of cost-effective high-volume manufacturing. The MEA is crucial and represents a significant cost to PEMFC manufacturing. Manufacturing the electrode components for MEAs at high volumes can reduce production costs while delivering on the forecasted industry demands. Roll-to-roll is a mature coating technology applied in various manufacturing industries such as batteries, printed electronics, microelectronics, photovoltaics, printing, paper consumables, etc., with huge potential for PEMFC cell manufacturing. While the high-volume production process for MEA manufacturing differs from laboratory-scale, the MEA structure remains unchanged. Roll-to-roll is a continuous coating process with speeds of 10 m/min achieved. In this paper, Microgravure and slot-die coating methods were adopted and have shown promising outcomes for producing gas diffusion electrodes for MEAs. An overview of the Microgravure and slot die coating methodologies is provided and a discussion on preliminary results and challenges presented. Work on Microgravure gas diffusion electrode manufacturing has already achieved comparable performance with spray-coated gas diffusion electrodes. The influence of coating parameters and drying on the coated catalyst layer quality is discussed.

Keywords: polymer electrolyte membrane fuel cell, gas diffusion electrode, slot-die, Microgravure, roll-to-roll, coating window

The full paper will be published in the SAIMM Journal

Cecil Felix
Senior Specialist
Mintek

Dr. Felix is a Senior Scientist working on fuel cell manufacturing activities at Mintek. He holds a PhD in Chemistry from the University of the Western Cape and has over 12 years of experience in renewable energy technologies. His main areas of expertise lie in catalyst development for PEM water electrolysers and MEA development for PEM fuel cells. Dr. Felix has also been involved with student-supervision and has published his work in peer-reviewed scientific journals. He believes South Africa is uniquely positioned to revolutionise its economy through hydrogen technology due to the country's abundant minerals and renewable resources.

Optimisation of hydrocarbon-based membrane electrode assembly for proton exchange membrane fuel cells

B. K. Tawa, F. Van Schalkwyk, D. Susac
University of Cape Town, South Africa

Given the increasing global energy demand, hydrogen-based energy technologies present a viable solution to address the gradual depletion of fossil fuel reserves and their associated environmental impacts. Proton exchange membrane fuel cells (PEMFCs) efficiently convert hydrogen fuel into electrical energy, offering significant potential to reduce carbon emissions in the automotive sector, stationary and portable power generation systems [1]. The demand for sustainable and cost-effective materials in PEMFCs has led to a growing interest in hydrocarbon-based ionomers as alternatives to conventional perfluorosulfonic acid (PFSA) materials. While PFSA materials offer excellent proton conductivity and durability, their high cost, complex manufacturing processes, and environmental concerns due to their fluorinated structure limit their long-term sustainability [2]. Hydrocarbon-based proton exchange membranes (PEMs) present a viable alternative; however, they are known to have lower durability compared to PFSA-based membranes [3]. This study aims to evaluate the potential of hydrocarbon-based PEMs and their suitability as alternatives to PFSA materials by investigating the durability of hydrocarbon PEMs and assessing the performance of hybrid membrane electrode assemblies (MEAs) incorporating both hydrocarbon PEMs and PFSA-based catalyst layers. Additionally, the influence of solvent systems, and coating conditions on membrane durability and electrochemical properties is explored to identify optimal processing parameters. The outcomes of this research aim to provide insights into enhancing the durability and operational stability of hydrocarbon-based MEAs, paving the way for developing efficient, cost-effective, and environmentally friendly alternatives for PEMFC technology.

Keywords: hydrogen fuel cell, PEMFC, hydrocarbon membrane

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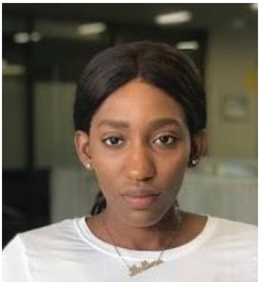

Bettina Kaine Tawa

Chemical Engineer
University of Cape Town (HySA Catalysis)

I am Bettina Kaine Tawa, a chemical engineer with a background in research and technology development for hydrogen fuel cells. I hold a Honours degree in chemical engineering, and I am currently pursuing a Master's degree, where I am optimising the durability of hydrocarbon-based proton exchange membranes compared to traditional perfluorosulfonic acid (PFSA) membranes in proton exchange membrane fuel cells (PEMFCs).

Alongside my academic pursuits, I am also actively working in the field of chemical engineering, where my focus is on optimizing membrane electrode assembly (MEA) for PEMFCs. With a commitment to advancing hydrogen fuel cell technology, I aim to contribute to the development of cost-effective, high-performance alternatives that support the global transition to clean energy. My work aligns with South Africa's growing green hydrogen economy, and I am excited about the opportunities to bridge the gap between research and industrial applications in sustainable energy solutions.

The effect of carbon-supported and -unsupported irox on reversal tolerance and anode durability

U. Nyambi, H. Moydien, D. Susac
University of Cape Town, South Africa

Fuel cell technology is gaining increasing interest as a potential solution for sustainable energy and reduced greenhouse gas emissions. Essentially, a fuel cell converts chemical energy into electrical energy, generating only water and heat as by-products. Proton exchange membrane fuel cells (PEMFCs) can operate at low temperatures (60-90°C), produce high power density and have a quick start-up – making them favourable for automotive applications. Despite the promising nature of this technology, it still encounters significant challenges relating to cost and durability.

PEMFCs operate under a continuous supply of hydrogen fuel. However, fuel starvation can occur due to blocked bipolar plate flow channels, rapid load change, uneven gas distribution etc. When a PEMFC experiences hydrogen fuel starvation, it cannot sustain the necessary protons and electrons from the standard hydrogen oxidation reaction (HOR), resulting in a significant increase in the anode voltage, which can lead to cell reversal. In this state, the fuel cell seeks alternative sources of electrons and protons, initiating carbon corrosion and subsequently degrading the anode catalyst layer (ACL). To mitigate this damage, an oxygen evolution reaction (OER) catalyst is incorporated into the ACL to promote water electrolysis over carbon corrosion [1].

In this study, two commercial catalysts were investigated for OER purposes: carbon-supported and -unsupported iridium oxide (i.e. IrOx/C and IrOx respectively). To assess their tolerance to reversal conditions, two different accelerated stress tests (ASTs) were employed –galvanostatic and pulsing. These tests are used to predict the anode's real-life behaviour during reversal conditions by applying different stress modes. In the galvanostatic AST, a constant current is maintained until a predetermined voltage is reached, while in fuel starvation mode. In the pulsed AST, cell reversal is induced by alternating between fuel starvation and normal operation mode [2].

The current investigation indicates that for both OER catalyst systems subjected to the galvanostatic AST, the OER catalyst stopped performing water electrolysis after a certain period and thereafter followed predominant carbon corrosion. The pulsed AST permitted a direct comparison between the two systems by monitoring the end of test performance after a specified number of pulses. IrOx-unsupported demonstrated a longer water electrolysis time compared to IrOx/C.

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Keywords: PEMFC, fuel starvation, galvanostatic, pulsing, AST, OER catalyst, water electrolysis time

Ursula Nyambi

Technologist
HySA Catalysis

Ursula specializes in the development of cutting-edge fuel cell technology at HySA Catalysis. She focuses on the fabrication, process development and testing of Membrane Electrode Assemblies (MEA), directly contributing to the advancement of sustainable energy technologies.

At HySA Catalysis, Ursula contributes to the establishment and implementation of fuel cell testing protocols, as well as the development of novel ink and MEA fabrication methodologies that enhance the performance and efficiency of fuel cell systems. As a member of the technology development team, she not only focuses on technical innovations but also plays an active role in supporting the growth of knowledge within the field and sharing her expertise through specialized training.