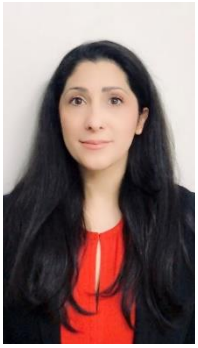
Proceedings of the 15th International Green Energy Conference
IGEC2023-331~335 (invited)
July 10-13, 2023, Glasgow, UK

Special Session: Fuel Cells and Electrolyzers

Session Description:

In order to mitigate the rising levels of greenhouse gases (GHG) in the atmosphere, which is a leading contributor to climate change, the world's current energy paradigm is undergoing a radical transformation. Development of an at-scale, clean hydrogen economy is a strategic priority and required to diversify our future energy systems, generate economic gains, and achieve net zero emissions by 2050. This special session will cover the latest developments and advancements in fuel cells and electrolyzers from fundamentals, to advanced materials, design, engineering, products, and applications. It will be of particular value and interest to those in the relevant fields.

Session Organizer(s):



Samaneh Shahgaldi
Hydrogen Research Institute (HRI)
Université du Québec à Trois-Rivières (UQTR)

Session Contents:

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Topic 1: Recent Development in Oxygen Reduction Reaction Electrocatalyst

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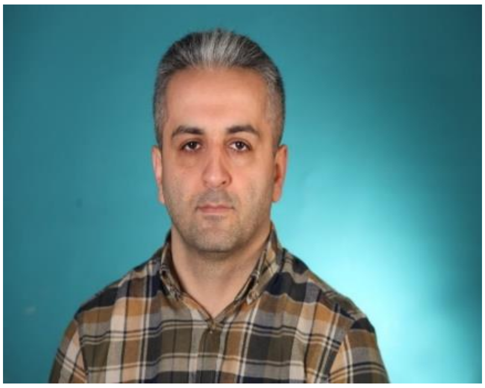
Abstract:
The oxygen reduction reaction (ORR) is an important electrochemical reaction that occurs in fuel cells, metal-air batteries, and other electrochemical devices. ORR electrocatalysts are materials that can facilitate the ORR and improve the efficiency of these devices. ORR is the most important cathodic process in polymer electrolyte membrane fuel cells. Among all catalysts evaluated, Pt is still the best catalyst for ORR. The major obstacle with Pt is that it belongs to the platinum group of metals, which are rare metals, hence too expensive for feasible commercialization of fuel cells.
In recent years, there have been several developments in ORR electrocatalysts due to their high surface area and tunable electronic properties. One of the most promising recent developments has been the use of single-atom catalysts (SACs). SACs consist of individual metal atoms dispersed on a support material and exhibit high ORR activity and durability. Noble metal alloys (bimetallic and trimetallic), and composite electrocatalyst have also been studied as ORR electrocatalysts and have shown significant promise. Additionally, there has been significant interest in developing non-precious metal catalysts such as heteroatom-doped carbon materials, metal-organic frameworks. Machine learning-assisted electrocatalyst design is also a growing area of research, with algorithms being used to predict the properties of new catalyst materials and guide the design of more efficient catalysts. These developments in ORR electrocatalysts show that there are many different approaches to improving the efficiency of electrochemical devices. By continuing to explore new materials and design strategies, researchers may be able to develop even more effective ORR electrocatalysts in the future, revolutionize fuel cell technology and pave the way for clean and renewable energy sources.



Dr. Mohammad Soleimani Lashkenari is currently a researcher (associate professor) in the Amol University of Special Modern Technologies (AUSMT), IRAN. He received his PhD degree from the Babol Noshirvani University of Technology, Iran in October 2014 and joined AUSMT in February 2015. His research interest is related to deploying functional nanocomposites (carbon based materials, MOFs, magnetic structures) as an active electrode for MOR, ORR/OER, CO2 reduction, and HER reactions and supercapacitors. He is looking for the use of scalable synthesis methods for different active electrode materials as well as improving their performance and stability in functional conditions based on the targets of the well-known roadmaps.

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Topic 2: Energy management of fuel cell vehicles: from the stack behavior to the hybrid power source integration.

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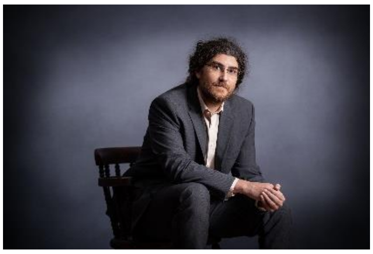
Abstract:
Over its lifetime, the performance of a fuel cell varies greatly. For example, in a vehicular application, end-of-life is often associated with a 20% drop in maximum power. The maximum power, maximum efficiency and currents needed to reach these operating points change as the fuel cell ages. The system's control and energy management must then be modified to take account of this ageing process. The objective is to ensure the best energetic performances along the fuel cell lifetime. However, these aging phenomena are difficult to model and we are currently unable to predict, in simulation, the evolution of fuel cell behavior over several thousand hours. This lecture explores different methods of adapting power management to changes in performance without resorting to complex aging models.
Keywords: 3-5 keywords



Loïc Boulon received the master degree in electrical and automatic control engineering from the University of Lille (France), in 2006. Then, he obtained a PhD in electrical engineering from University of Franche-Comté (France). Since 2010, he is a professor at UQTR (Full Professor since 2016) and he works into the Hydrogen Research Institute (Deputy director since 2019).
His work deals with modeling, control and energy management of multiphysics systems. His research interests include hybrid electric vehicles, energy and power sources (fuel cell systems, batteries and ultracapacitors). He has published more than 140 scientific papers in peer-reviewed international journals and international conferences and given over 40 invited conferences all over the world. In 2022, he is in the top 10 of the world most prolific authors of the topic "Proton Exchange Membrane Fuel Cell (PEMFC)" and in the top 20 of the topic "Plug-in Hybrid Vehicles", in Elsevier SciVal.
In 2015, Loïc Boulon was general chair of the IEEE-Vehicular Power and Propulsion Conference in Montréal (QC, Canada). Prof. Loïc Boulon is now VP-Motor Vehicles of the IEEE Vehicular Technology Society and he found the "IEEE VTS Motor Vehicle Challenge". He has been the holder of the Canada Research Chair in Energy Sources for the Vehicles of the future and he is now the Director of the Réseau Québécois sur l'Energie Intelligente.

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Topic 3: Ultra-Thin Metallic Bipolar Plates of PEMFCs: Manufacturing Methods and Common Defects

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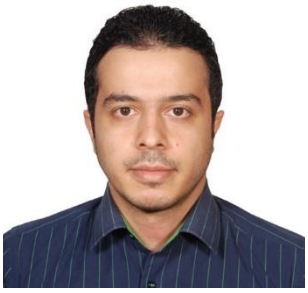
Abstract: Polymer electrolyte membrane fuel cells (PEMFCs) have the potential to revolutionize the energy industry due to their high power density and fast start-up. However, the high manufacturing cost of PEMFC components remains a major obstacle to their commercialization. One of the most critical components of PEMFCs is the bipolar plate, which can account for a significant portion of the cost and weight of the fuel cell. To overcome this challenge, various material and manufacturing methods have been proposed.

In this talk, we will focus on ultra-thin metallic bipolar plates, which offer several advantages over other types of bipolar plates, including lower weight and cost. We will discuss the various manufacturing methods (short description about each process and highlight the advantages and disadvantages) and common defects associated with ultra-thin metallic bipolar plates, and summarize recent progress in this field. Specifically, we will highlight our lab's research on addressing key challenges associated with the production of ultra-thin metallic bipolar plates, including wrinkling, thinning, dimensional accuracy, and fracture. We will demonstrate how we use a combination of numerical and experimental methods to examine the root causes of these defects, as well as strategies for preventing and mitigating them to improve the quality of the final product. Overall, this talk aims to provide attendees with a comprehensive understanding of the manufacturing methods and common defects associated with ultra-thin metallic bipolar plates. We will also emphasize the practical implications of our research, and how our findings can help improve the efficiency of the production process and achieve high-quality plates for fuel cell applications.



Dr. Hossein Talebi-Ghadikolaee is an assistant professor of Mechanical Engineering at the University of Kashan, Kashan, Iran. He received his B.Sc. and M.Sc. degrees in Mechanical Engineering from Babol Noshirvani University of Technology in 2013 and 2015, respectively, and went on to complete his Ph.D. in Mechanical Engineering at Tarbiat Modares University, Tehran, Iran, in 2019. He has been a member of Iran's National Elites Foundation since 2015. His research interests' focus on a variety of topics related to metal forming processes, plasticity theory, dynamic and quasi-static material characterization, deformation mechanics and ductile fracture analysis, fuel cells, and the fabrication process of ultra-thin metallic bipolar plates. In particular, he has been involved in projects related to the manufacturing process of ultra-thin metallic bipolar plates, predicting forming defects, and characterizing mechanical behavior of materials. He has made significant contributions to the field, with over 50 peer-reviewed articles published in high-impact journals, conferences, and book chapters. His work has helped to advance the understanding of manufacturing processes of sheet metal, material characterization, and ductile fracture analysis of metallic component.

Topic 4: Investigate the role of cellulose acetate and oxidized carboxymethyl cellulose polymer electrolytes in LIBs

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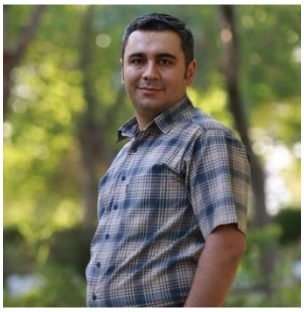
Abstract: There are significant worries about environmental pollution due to the ever-growing usage of fossil fuels. Thus, the need for a clean, affordable, and efficient energy storage supply has never been more critical. In this regard, lithium-ion batteries (LIBs) are deemed as a safe source of energy storage devices and have numerous applications within the electronics industry. However, the leakage of liquid electrolytes (which are principally nephrotoxic and flammable) along with dendrite growth are the major drawbacks in conventional LIBs; hence, there is a high demand to produce eco-friendly novel LIBs for a sustainable society. Polymer electrolytes are one of the most effective alternatives to liquid electrolytes to extend LIBs' safety; Nevertheless, they suffer from low ionic conductivity and charge capacity. In our works, to overcome these tremendous disadvantages, cellulose acetate and oxidized carboxymethyl cellulose polymer electrolytes obtained from sugarcane and cotton, respectively, were utilized as sustainable polymer electrolytes in LIBs. Then, to investigate the effect of crosslinker length on ion transfer behavior, short (citric acid) and long (polyvinyl alcohol) chain crosslinkers were used to create polymer networks; Finally, the performance of prepared electrolytes in both solid and gel state was studied.



Dr. Amir Rezvani-Moghaddam is an Assistant Professor at Faculty of Polymer Engineering at Sahand University of Technology, Tabriz, Iran.His main research interests are in novel coatings and hybrid polymer nanocomposites using novel nanomaterials. His research also includes nanomaterials' synthesis, lithium-ion batteries, fluorescent materials and carbon dots. He leads the Ink and Coating LAB (INKOAT LAB) at the Faculty of Polymer Engineering at the Sahand University Technology in Iran. INKOAT LAB performs fundamental and applied research in polymer science, coatings technology and Inkjet ink industry. INKOA LAB has made contributions in areas like novel hybrid polymer nanocomposites, novel coatings and inkjet inks. INKOAT LAB research group is highly engaged in generating new knowledge related to novel coatings, and the design of products for high-tech applications of industrial interest.

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Topic 5: Anion Exchange Membrane Fuel Cells for Green Energy Conversion

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Abstract: Low-temperature fuel cells - such as proton exchange membrane fuel cells (PEMFCs), possess high power density (>1 W cm^{-2}) and are thus considered for electrochemical propulsion. PEMFCs are now featured in the electric vehicle – Toyota Mirai. However, with the high cost of cell components, their market-level penetration is challenging. Therefore, significant research efforts are dedicated to reducing the cost of cell components, mainly catalysts, membranes, air-loop, and the balance of the plant. Despite that, the cost reduction has been stagnant for the last 5 years and has not been able to achieve the ultimate cost target set by the United States Department of Energy (US DOE) — \$30/kW to make it competitive with internal combustion engines. On the other hand, newly emerging anion exchange membrane fuel cells (AEMFCs) offer several advantages over matured PEMFCs mainly due to (i) the non-precious metal chemistry, (ii) abundant and affordable materials – for instance, transition metal catalysts such as Co, Fe, and Mn typically coordinated with four nitrogen atoms in a carbon matrix or metal-free heteroatom doped carbon to catalyze oxygen reduction reaction (ORR) at the cathode, (iii) low-cost anion exchange membranes, and (iv) significant reduction in the balance of the system cost.

These advantages of the AEMFCs are promising and inspire market-level deployment of fuel cell technology in the coming future across the world. In this presentation, I will be addressing several aspects of the AEMFC technology: (i) design of CeO_x-Pd/C as a Pt-free anode catalyst by engineering the interfacial contact area, (ii) tailoring the catalyst support interactions for AEMFCs anode, and (iii) current challenges and prospects of AEMFC technology.

Dr. Ramesh Kumar Singh is currently working as an Assistant Professor in Vellore Institute of Technology, Vellore, India. Dr. Singh received his integrated M.Sc.-Ph.D. degree from the Indian Institute of Technology Bombay, on the development of low-cost Pt core oxygen reduction reaction (ORR) catalyst and used electrochemical impedance spectroscopy (EIS) to understand the underline physical cell process of ORR. He then pursued his postdoctoral research at Ariel University, Israel, with Prof. Alex Schechter, where he focused on the development of new electrocatalysts for urea oxidation relevant to fuel cell technologies. He then joined the laboratory of Prof. Dario R. Dekel, at the Technion - Israel Institute of Technology, as a postdoctoral fellow, where he focused on the development of Pt-free hydrogen oxidation reaction catalysts, carbide-support, and low-cost metal-free ORR catalysts and their integration in anion exchange membrane fuel cells. Currently, his work focuses on developing efficient metal-oxide support for oxygen reduction catalysts, green hydrogen production, ion-exchange membrane development and metal-oxide support.