

that TPBs did not change with increasing thickness. Also, the faradaic efficiency of hydrogen production maintained around 80% whether cathodic thickness. It is indicated that supplied electrons could transport smoothly in SFM cathode whether thickness.

EF05.09

Design of Anode Functional Layers for Protonic Solid Oxide Electrolysis Cells [Chunmei Tang](#), Sho Kitano, Hiroki Habazaki and Yoshitaka Aoki; Hokkaido University, Japan

Protonic solid oxide electrolysis cells (P-SOECs) are considered as one of the most efficient and cost-effective devices for hydrogen production from renewable electricity. P-SOECs based on proton-conducting perovskites, i.e., $\text{Ba}(\text{Ce}, \text{Zr}, \text{M})\text{O}_{3-\delta}$ ($\text{M} = \text{Y}, \text{Yb}$, etc.) enable an intermediate operating temperature region (400–600 °C) due to the low activation energy required for proton conduction (0.3–0.6 eV). One of issues in P-SOECs is a lack of suitable anode materials to promote anode reaction with oxygen evolution, thereby increasing the conversion efficiency. Many $\text{H}^+/\text{O}^{2-}/\text{e}^-$ triple conducting oxides, such as $\text{BaCo}_{0.4}\text{Fe}_{0.4}\text{Zr}_{0.1}\text{Y}_{0.1}\text{O}_{3-\delta}$ (BCFZY), $\text{PrNi}_{0.5}\text{Co}_{0.5}\text{O}_{3-\delta}$ (PNC), $\text{PrBa}_{0.5}\text{Sr}_{0.5}\text{Co}_{2-x}\text{Fe}_x\text{O}_{5+\delta}$ (PBSCF), $\text{NdBa}_{0.5}\text{Sr}_{0.5}\text{Co}_{1.5}\text{Fe}_{0.5}\text{O}_{5+\delta}$ (NBSCF) and $\text{PrBa}_{0.8}\text{Ca}_{0.2}\text{Co}_2\text{O}_{5+\delta}$ (PBCC) have been explored to spatially expand reaction zone to the whole anode particles. The triple conductivity of the anode materials has been found to be important to encourage the charge transfer to reactant and alternatively to suppress the hole injection to electrolyte. Herein, we demonstrate that both the steam electrolysis performances and efficiency of P-SOECs with $\text{BaZr}_{0.6}\text{Ce}_{0.2}\text{Y}_{0.1}\text{Yb}_{0.1}\text{O}_{3-\delta}$ (BZCYYb6211) electrolyte can be drastically improved by a use of $\text{H}^+/\text{O}^{2-}/\text{e}^-$ triple conducting $\text{Ba}_{0.95}\text{La}_{0.05}\text{Fe}_{0.8}\text{Zn}_{0.2}\text{O}_{3-\delta}$ (BLFZ) thin film (~140 nm) as anode functional layer (AFL) at the interface of electrolyte and conventional $\text{La}_{0.6}\text{Sr}_{0.4}\text{Co}_{0.2}\text{Fe}_{0.8}\text{O}_{3-\delta}$ (LSCF) anode. The electrochemical analysis clarifies that BLFZ AFL can significantly promote interfacial proton transfer at anode-electrolyte interfaces, resulting in low interfacial resistivity, and provide the reaction zones extended overall the surfaces of AFL and thus promote the anodic reaction without long range diffusion of oxygen species from gas-anode-electrolyte triple phase boundary (TPB) to LSCF anode surfaces. Hence, the BLFZ cell yields high electrolysis current of 570 mA cm^{-2} at 1.3 V under 600 °C benefiting from the minimal ohmic and polarization resistances (0.58 and 0.46 $\Omega \text{ cm}^2$), and an increased efficiency from 46% to 75% in comparison to the cell without BLFZ AFL at 500 °C. These results reveal that effective AFL can boost anodic reaction and optimize efficiency of P-SOECs.

EF05.10

Highly Active Non-Precious Metal Oxide and Carbon Nanopstructure Composite for Sea Water Reduction [Seung Hyun Hur](#), Jayasmita Jana and Tran Van Phuc; University of Ulsan, Korea (the Republic of)

Sea water, being abundant at earth surface, can become a promising energy source for generation of hydrogen fuel during electrolysis. However, the limitations including evolution of toxic chlorine gas as counter reaction of hydrogen evolution, catalyst poisoning, catalyst stability, and corrosion of electrodes are to be surmounted during electrocatalysis of seawater. Hence, along with mechanical methods for suppressing of chlorine evolution and designing of stable as well as efficient catalysts are needed as well. Recently, different nonprecious metal functionalities are being engineered in search of a stable, low cost, and efficient electrode material. It has been observed that the presence of carbon support on the metal oxide composite increased the electroactive surface area and catalytic activity. In this regard, an amorphous carbon nanosphere supported $\text{CuO}/\text{Co}_3\text{O}_4$ composite has been synthesized through heat treatment (CCuU). The synergism within spinel Co_3O_4 and monoclinic CuO boosted the electrocatalytic activity. CCuU was used as cathode material towards alkaline seawater a system. showed overpotential of 73 mV to attain the current density of 10 mA cm^{-2} , Tafel slope of 47 mV dec^{-1} , which are one of the lowest values among ever reported. In addition, the composite was stable enough and showed almost unaltered activity and morphology over long time chronopotentiometric study. Such amorphous carbon nanoparticle supported nonprecious metal oxide composites being first time reported for alkaline seawater electrolysis, would pave the way of designing different mesoporous nonprecious metal based electrocatalysts towards seawater electrocatalysis.

EF05.11

Non-Toxic (HF-Free) Synthesis of MXene and There Optimization for H₂ Evolution Activity and Stability [Ranjit D. Mohili](#), Monika Patel and Nitin K. Chaudhari; Pandit Deendayal Energy University School of Technology, India

MXenes are highly conductive, temperature resistant, chemically stable, and possess good cocatalytic property; and denoted by a general formula $\text{M}_{(n+1)}\text{X}_n\text{T}_x$ (M , X , and T stand for transition metal, carbon/nitrogen, and surface terminations such as OH, O, Cl, F, and etc. respectively and $n = 1-3$). In general, MXenes can be synthesized using hazardous HF by selectively etching out A layer from MAX (where A= 13-16 group element) phase precursors. In this work, we report MXene synthesized by non-toxic (HF-free) novel etching route. The resulting MXene has appreciably high conductivity, numerous hydrophilic functionalities (-Cl, -OH and =O) on its surface, and enhanced electrocatalytic performance. The MXene synthesized by this unique and non-toxic approach shows almost complete and successful etching of 13-16 group element and shows improved electrocatalytic H₂ evolution performance. To obtain layered structure of MXene, detailed study into the delamination of MXene is carried out in suitable solvent followed by SEM-EDX, TEM and X-Ray Diffraction study. Electrochemical water splitting test of this uniquely prepared MXene is also obtained.

Keywords: MXene, Two-Dimensional (2D), MAX, HF-free, Water splitting, Hydrogen evolution reaction

EF05.12

Effects of Irradiation Conditions on LDPE-Based Anion Exchange Membranes Properties—Performance and Stability [Andrey S. Barbosa¹](#), [Ana Laura G. Biancolli¹](#), [Alexandre Jose C. Lanfredi²](#), [Orlando Rodrigues Jr¹](#), [Fabio Fonseca¹](#) and [Elisabete I. Santiago¹](#); ¹Instituto de Pesquisas Energeticas e Nucleares, Brazil; ²Universidade Federal do ABC, Brazil

Anion exchange membranes (AEM) are polymeric solid electrolytes used in solid electrolyte-based electrochemical devices, such as fuel cells. This type of material has gained great emphasis in recent decades due to its high versatility and low cost when compared to well-established proton exchange membranes (PEM). Radiation-induced grafting (RIG) is a technique used in the preparation of polymeric AEMs. In this technique, the base polymer is copolymerized (grafting) with monomers derived from styrene by using radiation sources, such as electron beam and gamma rays, and followed by functionalized with quaternary ammonium groups (QA), whose are responsible for anion conduction properties. The properties of AEMs are highly influenced by the characteristics of the functional group, but also by the structure of the former polymer. The irradiation conditions, such as atmosphere (inert and/or oxidizing), temperature and absorbed dose during the irradiation of the base-polymer have been poorly explored in the literature but have shown to be fundamental in the understanding of AEM properties as well as the obtaining membranes with enhanced performance and stability. In this context, this work presents a systematic study of the influence of the irradiation conditions of low-density polyethylene (LDPE) films on the physical chemistry properties of the LDPE-grafted AEMs. The results show that the degree of grafting, degree of crosslinking, OH⁻ conductivity, stability and performance of AEMs in fuel cell are directly influenced by the irradiation. Impedance spectroscopy results showed that LDPE film irradiated at room temperature and air atmosphere achieves AEM conductivity of 120 mS cm^{-1} , while LDPE film irradiated at low temperature (-10 °C) the AEM conductivity increases up to 210 mS cm^{-1} . Such a result is highly related to fuel cell performance that, in this case, lead to an increase in power density from 800 mW cm^{-2} to 1100 mW cm^{-2} . Herein, it was also shown that the stability of membranes can be improved by more than 50% when the LDPE film is irradiated at low temperature. Thus, the conclusions of this study will help to understand and choose the best irradiation conditions for the preparation of anion exchange membranes for application in electrochemical devices.