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Elucidating the Impact of Temperature, Heating Duration, Doping and Co-Doping towards the Synthesis of Photocatalytic Active TiO₂ with Tunable Optical Properties

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Abstract

The TiO₂ semiconductor plays a paramount role as an active photocatalyst mainly due to its photo-induced electron transfer properties. The metastable anatase phase is widely accepted to have the most photoactive activity in catalytic applications as opposed to rutile TiO₂. This is mainly due to the significantly lower recombination rate of electron pairs possessed by Anatase TiO₂. Unfortunately, the high recombination rate in anatase TiO₂ hinders its application as a functional photocatalyst. Therefore, it is crucial to enhance the photocatalytic activity of anatase TiO₂ by modifying its optical properties, morphological properties, and crystal facets. The study aims to provide a benign synthesis method for TiO₂ with co-exposed {001}/{101} anatase TiO₂ facets. The synthesis was conducted via a one-pot reflux condensation method. A concise evaluation of the effect of different synthesis heating durations, temperatures, and doping materials on the crystal phase, morphology, and photocatalytic performance of TiO₂ was conducted. Anatase TiO₂ with a high percentage of the high-energy {001} facet can boost adsorption and photocatalytic performance as opposed to anatase TiO₂ dominated by a thermodynamically stable {101} facet. The incorporation of non-metal dopant (HF) acts as a surface modifier, leading to the enhancement of {001} facet percentage. The evaluation of the functionalities of HCl in paving the way towards the formation of a mid-gap state was thoroughly conducted. The reduction of the band gap of the anatase TiO₂ can clearly be identified from the shifts in the adsorption band towards higher wavelengths. From the findings, it was found that the synergistic effect of co-doping anatase TiO₂ with the two non-metal dopants plays an important role in altering the rate of carrier transfer-recombination. Remazol Brilliant Blue (RBBR) was chosen as the target pollutant to evaluate the photocatalytic performance of co-doped TiO₂. It was found that 86.89% of RBBR was successfully degraded within 120 minutes with broad spectrum irradiation.

Keywords: *titanium dioxide; co-exposed facet; non-metal doping; photocatalyst*

NiS and Mo₂C as Co-catalyst of TiO₂ Nanotube Photoelectrode to Enhance Photoelectrochemical Water Splitting Performance

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Abstract

Titanium dioxide (TiO₂) is a well-researched photoelectrode material for photoelectrochemical (PEC) water-splitting applications. However, its light absorption is limited to only UV light due to its large bandgap, resulting in a quick recombination of photo-excited electrons and holes. Our research focuses on the attempt to enhance TiO₂ nanotube (NT) photoelectrode performance by using double materials that is Mo₂C & NiS, that are expected to function as co-catalyst and photosensitizer. Various techniques such as X-ray diffraction, field-emission scanning electron microscopy, X-ray photoelectron spectroscopy, UV-Visible spectroscopy, and photoelectrochemical measurements were used to characterize the morphology, optical properties and photocatalytic performance of the photoelectrode. Our results showed that the incorporation of NiS significantly enhanced the photocurrent density up to 1.65 mA cm⁻² as compared with Mo₂C/TiO₂ NT and TiO₂ NT were 1.40 mA cm⁻², 0.28 mA cm⁻², respectively. The incorporation of NIS has greatly enhanced the UV absorption efficiency to visible light absorption. This can be attributed to the synergistic effects between NiS and the intrinsic catalytic properties of the Mo₂C/TiO₂ NT structure. Our study provides valuable insights into the design and optimization of visible-light-driven photocatalysts for hydrogen production through photoelectrochemical water splitting.

Keywords: *Nickel Sulphide (NiS); Titanium Dioxide (TiO₂); Molybdenum Carbide (Mo₂C); Photoelectrochemical water splitting*

Modification of Gas Diffusion Electrode using Polyaniline and Polypyrrole for Microbial Electrosynthesis - A Comparative Study

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Abstract

Microbial electrosynthesis (MES) is a promising technology for converting CO₂ into value-added chemicals. As with other biotechnologies, achieving a high production rate by enhancing the interaction between biofilms and electrodes is the key to bioelectrochemical systems (BES). In this work, we investigated and compared the conversion of CO₂ by MES in reactors equipped with homemade gas diffusion electrodes (GDEs) fabricated using four different types of conducting polymers, namely polyaniline (PANI) and polypyrrole (PPY), synthesized via the chemical oxidation method. PANI-modified reactors experienced a faster start-up time of less than 20 days followed by PPY due to their higher hydrophilicity and surface area. Electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) demonstrated that PPY coating improved the electron transfer capabilities of the GDE. Up to 4400 ppm of acetate was produced in PANI-modified reactors after 24 days of operation, compared to 408 ppm in reactors equipped with PPY-modified GDEs. A maximum acetate concentration of 7500 ppm (production rate of 554.8 ± 267.5 ppm day⁻¹) was reached in reactors equipped with PANI-GDEs. After 60 days, in addition to acetate, 245 ppm of butyrate was produced in reactors equipped with PANI-coated electrodes, while less than 120 ppm was produced with PPY-modified GDEs. Concomitantly, the current density was increased to 3.2 ± 0.8 A m⁻², which was 2-fold higher than the PPY-modified GDE. SEM analysis showed a denser population of bacteria on PANI-coated GDEs, revealing PANI as a promising material for GDE fabrication over PPY.

Keywords: *microbial electrosynthesis; gas diffusion electrode; conducting polymer*

Influence of the Current Collector on the Structural and Electrochemical Properties of the $\text{LiNi}_{0.5}\text{Ru}_{0.5}\text{O}_2$ Electrode

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Abstract

Despite its high efficiency and fuel flexibility advantages, the SOFC often encounters problems when operated at high temperatures and requires a complex manufacturing process for a single cell consisting of different electrode materials. Therefore, a new configuration was developed using the same electrode materials to simplify the manufacturing process. In this study, a modified $\text{LiNi}_{0.5}\text{Ru}_{0.5}\text{O}_2$ electrode was presented as a possible electrode for a symmetrical solid oxide fuel cell. A total of three sets of symmetric cells were fabricated: S1 served as a control without a current collector, S2 with hand-painted silver paste, and S3 with a gold-sputtered coat. All symmetrical cells had an electrode with an active area of 1 cm^2 in $\text{LiNi}_{0.5}\text{Ru}_{0.5}\text{O}_2$ /SDC/ $\text{LiNi}_{0.5}\text{Ru}_{0.5}\text{O}_2$ configurations. Electrochemical impedance spectroscopy analysis was performed in both oxidized and reduced environments. The ASR values for S1 at 800°C were $5.92 \Omega \text{ cm}^2$ in air (cathode) and $5.41 \Omega \text{ cm}^2$ in an $\text{H}_2\text{:N}_2$ gas mixture (anode). S2 had an ASR of $0.78 \Omega \text{ cm}^2$ and $0.69 \Omega \text{ cm}^2$ in air and the gas mixture, respectively. For S3, with gold nanoparticle as the current collector that was coated for 10 seconds, the ASR values at 800°C were $2.44 \Omega \text{ cm}^2$ in air (cathode) and $2.08 \Omega \text{ cm}^2$ in an $\text{H}_2\text{:N}_2$ gas mixture (anode). FESEM micrographs of the cross-sectional area were analyzed to gain a better understanding of the interface between the printed electrode and the substrate (SDC electrolyte). The results indicate that the modified $\text{LiNi}_{0.5}\text{Ru}_{0.5}\text{O}_2$ with silver paste as a current collector has great potential as an electrode for symmetric solid oxide fuel cell applications.

Keywords: *Electrode, lithium, microstructural, electrochemical performance, symmetrical solid oxide fuel cell*

Microstructure Analysis of Laser Micro Welding for Thin Plate Stainless Steel (SUS430) In the Application of Metal-Supported Solid Oxide Fuel Cell (MS-SOFC)

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Abstract

Laser micro welding (LMW) is a manufacturing technology that uses a laser beam to fuse two or more pieces of material together, especially metal. LMW has been widely studied in a variety of industrial applications due to its advantages such as low heat input, deep penetration, low residual stress, and distortion when compared to conventional welding techniques. Nowadays, stainless steel grade 430 (SUS430) is becoming a popular material for laser micro welding in industry, especially in battery and fuel cell applications. However, as the metal thickness is reduced, LMW has posed challenges in the joining process. To investigate the properties of two thin plate SUS430 metals for the fabrication of metal-supported solid oxide fuel cell (MS-SOFC), non-destructive testing (NDT) such as Digital Detector Array (DDA) and Optical Microscopy (OM) are conducted to determine the position of the defect and the microstructure of the welded region. OM is also used to investigate the microstructure on the surface and the sub-surface of the thin SUS430 welded metals. The results show that the selected parameter of LMW has achieved the joining of two thin plate SUS430. The macrostructure and microstructure of each welded area were examined. According to DDA analysis, the defect gradually decreased with the use of low laser power and laser speed. The type, rate, and size of these defects have been evaluated through the analysis of the microstructure on the surface and the sub-surface of each sample. Therefore, these findings provide an excellent evaluation of the experimental research on the parameter of LMW in terms of alteration microstructure and defects in the welded area.

Keywords: Laser Micro Welding, Microstructure, Stainless-steel, Metal-Supported Solid Oxide Fuel Cell (MS-SOFC)

Effect of Calcination Temperature on the Structural and Electrochemical Behaviour of Li-based Cathode for Intermediate-Temperature SOFC Application

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Abstract

Developing high-performance and stable solid oxide fuel cells (SOFC) is crucial in addressing the thermal stress and degradation of cell components caused by high-temperature operation. A new strategy is needed to reduce the operating temperature of SOFC. To improve SOFC efficiency, the use of lithium (Li) as a cathode can be promising due to its ability to facilitate faster ion transport and higher reaction rates. This study proposes a promising approach to using a Li-based cathode by combining Li with cobalt (Co) to create $\text{LiCo}_{0.6}\text{Sr}_{0.4}\text{O}_2$ (LCSO). To investigate the effect of calcination temperature on the structural and electrochemical properties of the Li-based cathode, the researchers prepared a precursor made of Li, Co, and strontium (Sr) using the glycine-nitrate combustion method, which was then calcined at two different temperatures (800 and 900 °C) before ink formulation and symmetrical-cell fabrication. The crystal structure and composition of the developed LCSO were analyzed using X-ray crystallography. Electrochemical impedance spectroscopy was used to assess the electrochemical performance of the fabricated symmetrical cell, which provided information on the cell's resistance, related to its ionic and electronic conductivity. This study's results have significant implications for the field of SOFC research, especially in the development of low-temperature SOFC.

Keywords: *solid oxide fuel cell; intermediate-temperature SOFC; lithiated cathode materials; ion conductivity; symmetrical cell*

In-situ C-doped g-C₃N₄ Grafted on C, N Co-doped ZnO Micro-Flowers with Enhanced Photocatalytic Degradation of Bisphenol A and Hydrogen Generation

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Abstract

The in-situ hierarchical heterojunction photocatalyst consists of C-doped g-C₃N₄ (CCN) grafted on the C, N co-doped ZnO were successfully realized via simple bio-template hydrothermal approach. The resultants hierarchical heterojunction photocatalyst exhibited excellent UV to the near infrared absorption capability. The electrochemical analysis and photoluminescence spectroscopy revealed that the hierarchical heterojunction photocatalyst possessed excellent charge generation and separation efficiency. The resultant hierarchical heterojunction photocatalyst exhibited remarkable photocatalytic performance in the photodegradation of bisphenol and photocatalytic hydrogen evolution under simulated solar irradiation. The enhancement of photocatalytic performance was mainly attributed to the combined effect of hierarchical morphology, in-situ doping, and heterojunction formation.

Keywords: *bio-template; hierarchical; non-metal doping; heterojunction; photodegradation; hydrogen*

Microwave-Assisted Synthesis of PtSn Nanoparticles: Effect of Reaction Times on Morphology, Structural and Catalytic Activities for DMFC Applications

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Abstract

PtSn nanoparticles were synthesised using microwave irradiation at different reaction times (e.g., 40 s, 60 s, 90 s, 120 s, 150 s, 180 s, and 210 s). Agglomeration of cubic nanoparticles was formed when irradiated for 40 to 150 s, whilst agglomeration of irregular small particles was formed when the samples were microwave irradiated for 180 and 210 s. The average particles have been calculated using Image J software between the range of 5 nm to 20 nm. The surface roughness of the samples increased when irradiated for 210 s. The crystallinity of PtSn particles increased upon prolonging the reaction times with its structural phase change from the face-centred-cubic to the hexagonal phase of PtSn. Among the samples, the x-ray diffraction pattern of PtSn irradiated for 120 s is highly pure without the presence of SnO₂. The sample also exhibited high catalytic performance towards the oxidation of methanol, better than PtSn synthesised for 40 s in terms of resistance toward CO poisoning, and showed high stability for 1000 s.

Keywords: *PtSn; microwave-assisted; nanoparticles; reaction times*

Photoelectrochemical Properties Enhancement of Hydroxyapatite by Morphological Alteration Strategy: Impact of Surfactant

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Abstract

Hydroxyapatite (HAp) had promising potential in photocatalysis applications due to its tunable properties where the physicochemical properties of HAp can be tailored by doping or modifying its composition, morphology, and surface characteristic, allowing the fine-tuning of its photocatalytic performances. However, the typical HAp possessed irregular, agglomeration, wide band gap, and rapid photo-induced electron-hole pairs recombination which limit its ability for practical photocatalysis application. Therefore, this study emphasizes the morphologies alteration strategy to enhance the optoelectronic and photochemical properties with the presence of CTAB and P123 surfactant during hydrothermal synthesis. Based on the FESEM, UV-Vis spectroscopy analysis, and PEC measurement, the presence of surfactant induced the formation of well-constructed nanorod structures, narrower the band gap, and suppressed charge recombination, respectively. Besides, the HAp obtained by the presence of CTAB showed enhanced stability, charge separation, and suitable energy level for photocatalysis applications like hydrogen generation and CO₂ photoreduction.

Keywords: *Hydroxyapatite; Surfactant; CTAB; P123*

The Effects of Fe-doping towards the structural formation of ZIF-8 and ZIF-67 Based Electrocatalysts for Oxygen Reduction

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Abstract

Fuel cells have been investigated experimentally and theoretically for the conversion of chemical energy into electrical energy via electrochemical reactions. Proton Exchange Membrane Fuel Cells (PEMFCs) have been regarded as one of the most promising devices amongst other fuel cells due to their zero-pollutant emission and high energy efficiency. Nevertheless, the performance of PEMFC devices is hindered mainly by the relatively slow kinetics of the oxygen reduction reaction (ORR). Hence, the development of effective, stable, and economical, alternative electrocatalysts is critical for further implementation of PEMFCs. Zeolitic Imidazolate Frameworks (ZIF) based electrocatalysts have a significantly lower cost of production as compared to the Pt-based electrocatalysts, hence showing great potential. The study herein aims to synthesize ZIF-8 and ZIF-67-based electrocatalysts using the solvothermal method. The Fe-doped ZIF electrocatalysts are prepared using iron nitrate as the Fe precursor at varied weight ratios (1:0.25, 1:0.5, 1:1, and 0.5:1). The materials composition and structural formation of the undoped and Fe-doped ZIF electrocatalysts are then evaluated via physicochemical characterization which includes, BET, XRD and FESEM. The electrocatalytic activities of the undoped and Fe-doped ZIF electrocatalysts are studied through electrochemical analyses comprising cyclic voltammetry (CV) and linear sweep voltammetry (LSV). The Fe-doped ZIF electrocatalysts exhibited more promising structural characteristics as compared to the undoped ZIF-based electrocatalysts, hence significantly improving their ORR.

Keywords: *zeolitic imidazolate frameworks (ZIF); Fe-doping; oxygen reduction reaction (ORR)*

Surface Modification of MXene with Sufonic Group and Disulfonic Group

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Abstract

The usage of 2D materials as a filler in a membrane to compensate for membrane weaknesses and enhancing properties has been successfully proven. However, further improvement of the 2D materials is desirable to develop filler which can further compensate for weaknesses and enhance the properties of a membrane. The novel 2D material MXene has been tested/proven to have specific attune ability, where MXene has the potential to precisely modify surface termination group to match desired properties, aside from having 2D structure and its surface being always terminated with functional groups. This trait is seen to be the key/potential in many fields to achieve specific properties. In this study, MXene $\text{Ti}_3\text{C}_2\text{T}_x$, were surface modified with sulfonic groups to insert/replace terminations with SO_3H on MXene $\text{Ti}_3\text{C}_2\text{T}_x$ surface to achieve enhancement in proton conductivity. MXene $\text{Ti}_3\text{C}_2\text{T}_x$ were surface modified with sulfonic acid and disulfonic acid with different intercalant, and its resultant properties were studied. The surface modified MXene $\text{Ti}_3\text{C}_2\text{T}_x\text{-SO}_3\text{H}$ and $\text{Ti}_3\text{C}_2\text{T}_x\text{-2(SO}_3\text{H)}$ were characterized with SEM, FTIR, XRD and XPS.

Keywords: *MXene, attune ability, desired, 2D material, specific properties, surface modified*

Synthesis, Characterization and Electrochemical Performance of Ruddlesden-Popper Layered Perovskite Anode $\text{La}_{0.6}\text{Sr}_{1.4}\text{MnO}_4$ for the Application of Solid Oxide Fuel Cell

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Abstract

This study aimed to explore the fabrication process of a newly discovered Ruddlesden-Popper layered perovskite, $\text{La}_{0.6}\text{Sr}_{1.4}\text{MnO}_4$ (LSMO₄), followed by a comprehensive characterization of its properties, including its electrical conductivity and electrochemical performance. The LSMO₄ precursor powder was synthesized via the citrate-nitrate method and subjected to a calcination process at a temperature of 1000 °C for 6h. The X-ray diffraction analysis further confirmed the existence of LSMO₄ materials exhibiting a tetragonal structure with a K_2NiF_4 -type crystal lattice (space group $I4/mmm$). Additional characterization techniques such as Fourier-transform infrared spectroscopy, Brunauer-Emmett-Teller analysis, and field emission scanning electron microscopy were employed to investigate the functional groups, specific surface area, and surface morphology of the prepared sample. To investigate the electrical conductivity and electrochemical performance of the LSMO₄/LSGM/LSMO₄ symmetrical cell, an LSMO₄ film was screen-printed onto LSGM substrates and sintered at 1000 °C for 2h. The electrical conductivities of the symmetrical cells and their electrochemical performance were evaluated using the DC 4-point probe method and electrochemical impedance spectroscopy (EIS). The electrical conductivity of the symmetrical cell, measured under operating conditions of humidified 3 vol.% H_2O – 97 vol.% (H_2 : N_2 = 10: 90) was determined to be 1.53 S/cm at 800 °C. Meanwhile, EIS analysis revealed an area specific resistance of 1.52 Ωcm^2 for the symmetrical cells operating in similar environments. The results obtained from this study offer significant knowledge for the development and enhancement of anode materials based on R-P perovskites.

Keywords: *solid oxide fuel cell; Ruddlesden-popper layered perovskite; anode materials; electrical conductivity; area specific resistance*

The Impacts of Carbon Nanofiber-Titanium Dioxide as a Modified Microporous Layer on Direct Methanol Fuel Cell Performance

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Abstract

Direct methanol fuel cell (DMFC) is an alternative energy that can be used in portable applications such as chargers for mobile phones, and laptops. Membrane electrode assemblies (MEA) are the critical components of fuel cells that affect overall performances. The anode electrode is a component of the MEA and is essential for mass transport as well as electrochemical reactions. MEA contains several layers, namely two gas diffusion layers (GDL), two catalyst layers (CL), and a polymer electrolyte membrane (PEM) at the anode and cathode, respectively. GDL is divided into two layers, namely the backing layer (BL) and the microporous layer (MPL). The MPL plays an important role in transferring the reactant from GDL to CL effectively and removing the product more efficiently, reducing the contact resistance between CL and GDL, low cost, and ease of acquisition. The enhanced parameters of the anode electrode's microporous layer (MPL) are intended to provide high cell performance as well as high mass and product transfer efficiency. The parameters of the loading of MPL, the ratio of composition, the Nafion solution, and the influence of different methanol concentrations are varied. The effect of methanol concentration was found to influence the fuel cell performance, whereby by raising the methanol concentration, the performance increased. At the same time, MPL loading has an impact on performance. The high Nafion solution loading increases resistance. Modified MPL with high ratio CNF exhibits more stable performance due to the large content of CNF and gives more coverage. The maximum power density of 60.19 mW cm⁻² at 2 mg cm⁻², 40% CNF:60% TiO₂, 10% Nafion solution, and 6 M methanol concentration. The significant performance improvement has strengthened the potential of DMFC as green energy source that can be applied in portable applications.

Keywords: *Direct methanol fuel cell; Carbon nanofiber; Titanium dioxide; Microporous layer; Gas diffusion layer*

Mathematical Verification of $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3-\delta}\text{-Sm}_{0.2}\text{Ce}_{0.8}\text{O}_{1.9}$ Carbonate Perovskite Interconnect Coating Electric Conductivity for Solid Oxide Fuel Cell

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Abstract

Low temperature solid oxide fuel cell allows the ferritic stainless-steel convention instead of ceramic interconnect. However, chromium poisoning in interconnect deteriorates the solid oxide fuel cell performance during operation. This article encloses the $\text{Ba}_{0.5}\text{Sr}_{0.5}\text{Co}_{0.8}\text{Fe}_{0.2}\text{O}_{3-\delta}\text{-Sm}_{0.2}\text{Ce}_{0.8}\text{O}_{1.9}$ Carbonate (BSCF-SDCC) coating on ferritic stainless-steel interconnect with sintering different soaking time. BSCF-SDCC perovskite powder is developed by a low-speed ball milling technique in ethanol. The homogenous BSCF-SDCC perovskite powder is coated on SUS 430 ferritic stainless steel via electrophoretic deposition, then followed by varied sintering soaking times at 600°C. The morphological and crystallinity analysis confirms the uniform perovskite coating formed. Further increase of sintering time at 600°C increases the coating densification and crack is observed if the sintering time is longer. The area specific resistance (ASR) and the weight gain rate after oxidation is tested experimentally. A two-hour sintering time of BSCF-SDCC coating achieves the lowest ASR, indicating 0.0309 Ωcm^2 after 408 hours of oxidation. The parabolic weight gain oxidation rate constant of coating with two hours of sintering indicates a very low value, which is $3.24 \times 10^{-16} \text{g}^2\text{cm}^{-4}\text{s}^{-1}$. Mathematical ASR is established by a series of formulas with rate constant as the base to verify the experimental ASR and noted that the mathematical data is lower than the experimental study. However, the developed BSCF-SDCC perovskite coating demonstrates its potential as a promising SOFC interconnects coating at low temperatures.

Keywords: *Interconnect Coating; Mathematical Verification; Perovskite Composite*

Study of High-Performance Magnesium-Air Fuel Cell Using Corrosion Inhibitor

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Abstract

Magnesium-air fuel cell (MAFC) is a type of metal-air fuel cell that can be an alternative to lithium-ion batteries as an energy storage device. Among the advantages of MAFC are having a higher energy density, abundant resources, and being more environmentally friendly. However, MAFC suffers from severe corrosion and deposition problems due to the reactive reaction of the magnesium anode in the electrolyte thus reducing the durability of MAFC. Therefore, the study of the corrosion rate of Mg anode in optimizing the performance of MAFC using NaCl electrolyte and two corrosion inhibitors namely 4,5-dihydroxybenzene-1,3-disulfonic acid or Tiron ($C_6H_{10}Na_2O_8S_2$) and Trisodium phosphate (Na_3PO_4) at different concentrations were carried out. This study began with the development of an MAFC single cell. After testing several configuration factors, a MAFC single cell with a parallel inter-electrode position that holds 0.35 L electrolyte has been successfully developed. Next, a corrosion test was performed via the weight loss measurement method while the characterization of the corrosion product was analyzed using FESEM. The results of the study also found that MAFC cells using 10 wt.% NaCl electrolytes with Tiron and Na_3PO_4 concentrations of 0.15 wt% and 0.1 wt% respectively produced the highest power density of 48.6 mW/cm². The combination of Tiron and Na_3PO_4 in NaCl solution can reduce corrosion rate (5.26 mm/year) with an inhibition effectiveness of 58.42%. In conclusion, Tiron and Na_3PO_4 corrosion inhibitors in NaCl electrolyte can be used in the MAFC system to reduce the corrosion rate and improve MAFC performance, but the combination of these two inhibitors is not an ideal combination because it has an antagonistic effect.

Keywords: *magnesium-air fuel Cell; corrosion; inhibitor*

Analysis of The Change in Performance of Nafion Through Hot Press Treatment

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Abstract

In a previous study, the authors found a significant improvement in proton exchange membrane fuel cell (PEMFC) performance when Nafion 212 was subjected to multiple hot press cycles prior to use. To further investigate this effect, the researchers exposed Nafion 212 samples to various hot-pressing treatments and then evaluated their performance using different techniques to determine if changes to the membrane contributed to the performance improvement. The performance of a single cell was measured to verify whether the treatment caused a change in proton conductivity. However, durability testing of key fuel cell components showed significant differences depending on current and operating conditions. The results suggest that the hot press treatment has a significant effect on the electrical properties of Nafion 212, but the physical transformation of the polymer is not chemical in nature.

Keywords: *Nafion 212; hot-pressing treatment; durability*

Process Simulation and Economic Evaluation of 500 kW Polymer Exchange Membrane (PEM) Electrolysis System

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Abstract

The Balance of plant (BoP) configuration is important for reducing operating costs and improving the efficiency of an electrolysis system. Therefore, this study was conducted to develop a model and process simulation of a polymer exchange membrane (PEM) electrolysis system for hydrogen production. The model with 500 kW power capacity and 99.999% hydrogen purity are developed, and simulation is performed at the commercial level with Aspen Plus V10. The mathematical models of electrochemistry, mass, and energy balance for electrolyzer and BoP, including purification units, are developed to achieve the objectives of this study. The flash separator model is developed using the Rachford–Rice procedure. Techno-economics analysis is performed based on capital expenditure and operating expenditure. The process flow diagram of the electrolysis system is developed, and each process unit is described. Process simulation is implemented using Aspen Plus. Hydrogen purity of 99.999% at 10.208 kg/h and 11.878% BoP power consumption are obtained. The system efficiency is 55.126 kWh/kg, and the stack efficiency is 80.03%. The total capital expenditure is \$1,126,044.71, and the total operating expenditure is \$287,593.71 per year. The cost of hydrogen production obtained at \$4.01 per kg of hydrogen is comparable to that in the literature, showing that the commercialization of this system is feasible. This research model can be used as a basis for techno-economic analysis integrated with other processes, such as the dynamic simulation of the PEM electrolysis system.

Keywords: *polymer exchange membrane electrolyzer; hydrogen production; hydrogen purification; simulation process; Aspen*

Effects of Flow Field and Distribution Zone Design with Elliptical Baffles on Fluid Distribution

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Abstract

Proton Exchange Membrane Fuel Cell (PEMFC) is one of the key drivers in the boost of global hydrogen energy. However, it is known to be high cost and maintenance due to its hydrosensitive nature. This paper explored an innovative flow field design strategy via computational fluid dynamics (CFD) simulation to produce uniform fluid distribution with sufficient fluid resistance. These attributes ensure efficient transport phenomena and reaction kinetics for higher system efficiency. Three main parameters were analysed using air as fluid; (i) inlet/outlet turning angle (90°, 135° and 180°), (ii) density of elliptical baffles within the distribution zone area (0%, 50% and 100%), and (iii) flow field design comparison (conventional parallel (CP), modified fishbone (MF) and Tesla valve (TV)). Parameters (i) and (ii) were simulated with a CP flow field. Results showed that using 135° inlet/outlet angle with 100% baffle density significantly improved fluid distribution by improving uniformity by 6% and reducing pressure drop by half. For parameter (iii), the continuous fluid mechanism in TV design ensured uniform fluid flow throughout the flow field. CP and MF had lower pressure drop than TV by 147.70Pa and 133.87Pa respectively, but the fluid distributions were significantly uneven. Furthermore, flow channelling occurred in the MF design. The baffles also reduced the high-velocity levels in the TV flow field by raising fluid resistance with a minimal pressure drop increase of only 9.02Pa. Therefore, this study showed that the use of a TV design with a 135° inlet/outlet angle and 100% baffle density can significantly improve the fluid dynamics in a flow field.

Keywords: *baffle density; fluid distribution; biomimetic flow field*

Prelusive Study on Phase Formation and Chemical Stability of $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{Zr}_{0.1}\text{O}_{3-\delta}$ ($x = 0-1$) as Proton-conducting Solid Oxide Fuel Cell Electrolyte

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Abstract

Proton-conducting electrolytes are used due to their excellent ionic conductivity at intermediate temperatures compared to conventional solid oxide fuel cells. However, cerate-based (SrCeO_3 , BaCeO_3) and zirconate-based (SrZrO_3 , BaZrO_3) electrolytes have been found to exhibit common problems with poor chemical stability in wet-containing atmospheres and poor sinterability. These problems can affect the overall performance of the electrolytes in terms of conductivity and durability. In this study, the hybrid electrolytes of $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{O}_{3-\delta}$ with different Sr/Ba ratios ($x = 0-1$) are primarily investigated for phase formation and chemical stability with several characterizations to support the results. Phase analysis revealed that $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{O}_{3-\delta}$ ($x = 0-1$) was successfully synthesized via the glycine-nitrate method at a calcination temperature of 1100°C . A comparison of the relative density of the prepared pellets at a sintering temperature of 1500°C was performed, and the $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{O}_{3-\delta}$ ($x = 0-1$) showed high and preferable relative density percentage of proton-conducting electrolytes ($>90\%$). Additionally, the X-ray diffractometer analysis after exposure to a gas mixture composed of 10% hydrogen and 90% nitrogen, humidified (wet H_2/N_2), at a temperature of 700°C for 5 hours and boiling water for 24 hours confirmed the chemical stability of the $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{O}_{3-\delta}$ ($x = 0-1$) electrolytes. These results contribute to the knowledge of the potential of the $\text{Sr}_{1-x}\text{Ba}_x\text{Ce}_{0.7}\text{Y}_{0.2}\text{O}_{3-\delta}$ ($x = 0-1$) electrolyte, as well as the effect of the Sr/Ba ratio on the chemical stability of the electrolyte.

Keywords: proton-conducting electrolyte; solid oxide fuel cell; chemical stability

Fabrication and Characterization of Sulfonated Poly (ether ether ketone) based Polymer Electrolyte Membrane with Self-healing Property

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Abstract

Direct methanol fuel cells (DMFCs) have grown rapidly as a substitute power source, especially for portable applications, in recent decades. The essential components of DMFCs consist of a membrane electrolyte assembly (MEA) comprising a polymer electrolyte membrane (PEM), anode, and cathode electrodes. Nafion is the most used PEM in DMFCs due to its amphiphilic nature, which enhances proton conduction. However, due to its complicated production processes and performance degradation over time, this study investigates self-healable sulfonated poly (ether ether ketone) (SPEEK)-based composite membranes. The composite membrane is composed of SPEEK, poly (vinyl alcohol) (PVA), and silica, which are prepared using a simple solution casting and oven-drying method. The SPEEK-PVA-silica composite membrane improves methanol permeability by 75.72% compared to the Nafion 117 membrane, albeit with a minor decrease in proton conductivity. The SPEEK-PVA-silica membrane outperforms Nafion 117 in selectivity due to its excellent resistance to methanol. The composite membrane's self-healing ability is demonstrated by the recovery of 75.1% of methanol blocking following damage and healing compared to the undamaged membrane. PVA is believed to be responsible for providing the membrane with self-healing properties caused by its high amount of free hydroxyl groups in the polymer chain. In contrast, the methanol permeability of pristine SPEEK membranes that have been damaged and then healed is significantly higher than the original pristine SPEEK membrane, indicating that the pristine SPEEK membrane lacks the ability to self-heal. The SPEEK-PVA-silica membrane's high selectivity and self-healing property make it an attractive alternative for DMFCs.

Keywords: *polymer electrolyte membrane; SPEEK; self-healing*

Preliminary Investigation in Microbial Electrochemical Sensor Bioanodes: A Correlational Study between Biofilm Behaviour and Signal Produced

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Abstract

Electrogenic microorganisms have been explored extensively as biocatalysts for microbial electrochemical sensors (MESR) for the detection of toxicity, biochemical oxygen demand (BOD), dissolved oxygen (DO), and biodegradable organic matter (BOM) in wastewater. However, the study of biofilm behaviour and signal produced caused by disturbances in the surrounding environment remains lacking. Herein, stainless steel bioanodes with different modifications (carbon coated, flame oxidized, and graphene coated) were subjected to three simulated external disturbances, namely (i) starvation, (ii) aeration, (iii) air-dried and their recovery from such interferences. During the enrichment process, the current densities produced by control, carbon coated, flame oxidized, and graphene coated bioanodes were 0.65, 1.21, 1.14, and 1.44 A m⁻², respectively, which proved that graphene coated is optimum modification among its peers. In starvation and recovery test, 1 day starvation required 3 days of recovery period, while 3 days and 7 days starvation both required 6 days recovery period for the current signals to stabilize. High frequencies of noise signals were detected by all biosensors during the aeration test because of the introduction of air bubbles into the system. The fluctuation of current densities among the biosensors was also attributed to the collapsing of air bubbles near the biofilm causing them to detach from the electrode surface. In contrast to the starvation test, air-drying the bioanodes in 1, 3 and 7 days yielded relatively similar recovery periods when they were subjected back into the water source. Furthermore, graphene coated bioanode presented the greatest signal response towards model pollutants, followed by carbon coated bioanode, flame oxidized bioanode, and lastly the least responsive unmodified stainless steel bioanode. Carbon coated, flame oxidized and graphene coated bioanode demonstrated appropriate current density that was proportional to the loading rate of the model pollutants while the control barely recorded any signal changes.

Keywords: *Microbial Electrochemical Sensor; Surface Modification; Biofilm behaviour*

Influence of Ionomer Concentration and membrane thickness in MEA for Alkaline Fuel Cells

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Abstract

Alkaline anion exchange membranes (AEMs) have gained increasing attention because of the faster reaction kinetics compared to acidic media. However, at the electrodes, the anion conduction of the catalytic layer relies on the amount and distribution of the ionomer inside the catalytic layer. Consequently, the proper concentration of the ionomer is important to gain the best performance of the catalyst. Besides, the membrane thickness is also a significant parameter that affects system performance in AEM fuel cells. Thus, in this study, we focused on the membrane electrode assembly (MEA) preparation parameters for alkaline fuel cell performance optimization. The MEA consisted of catalyst-coated substrate layers containing a commercial anion exchange ionomer (Fumion) as a binding agent and a well-known commercial AEM (Fumasep). The study focused on the effect of ionomer concentration in the catalytic layer, and the effect of membrane thickness on the single-cell performance. The optimum Fumion concentration was found to be 50 wt%, and the thinnest Fumasep gave the highest power output. These findings offer a useful guide for MEA preparation in AEM fuel cells.

Keywords: *ionomer, anion exchange membranes, membrane electrode assembly, alkaline fuel cells*

A Novel Combined-mode Design for a MEMS-based Micro Passive Direct Methanol Fuel Cell

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Abstract

A small-scale micro direct methanol fuel cell was developed by utilizing silicon substrate-based electrode plates, where the flow field plate was fabricated with micro-electro-mechanical system technology. Modelling work was carried out to assist in the design of the anode and cathode plates to obtain the required configuration and geometric dimensions for the microfabrication process. A novel combined-mode anode plate was developed with an active-mode grid design and a passive-mode porous design for the flow field while the cathode plate was developed with a passive-mode design of square window-shaped through holes in a staggered arrangement. Silicon etching methods were used to form the desired flow field structures on the electrode plates with an active area of 1 cm². The single cell was put together by incorporating the electrode plates and membrane electrode assembly. A study on the feasibility and effectiveness of the new micro fuel cell was conducted and the performance test resulted in a maximum power density value of 1.86 mW/cm² at a voltage of 138.7 mV.

Keywords: *flow field; DMFC; micromachining*

An Integrated Heat Recovery System Design for a Fuel Cell Buggy with Hydrogen Preheating and Thermoelectric Generator

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Abstract

The integration of waste heat recovery systems with PEM fuel cells is a newly explored component for an energy-efficient powertrain solution. This study presents the design of an Integrated Heat Recovery (IHR) system for a lightweight 2 kW PEM fuel cell buggy. The IHR system captures and converts low-grade waste heat for hydrogen preheating, as well as for thermoelectric generation to enhance fuel cell performance. An experimental setup evaluates the performance and effectiveness of the IHR. The effects of key operating parameters, such as cruising speed, fuel cell load, and membrane rejuvenation, are systematically investigated. The results demonstrate that 83% of the waste heat was absorbed by the IHR and elevated the hydrogen fuel temperature by up to 16°C, leading to a 10.5% enhancement in electrical power output from the fuel cell. Additionally, the thermoelectric cells regenerated a maximum of 293 mW of electrical power, which can be used to power auxiliary systems. This initial study offers significant potential for improved energy efficiency in fuel cell powertrains, primarily through the process of hydrogen preheating.

Keywords: *fuel cell vehicle; waste heat recovery; hydrogen preheating; fuel pre-heating; thermoelectric generator*

Numerical Investigation of Dynamic Responses of Unitized Regenerative Proton Exchange Membrane Fuel Cell (URPEMFC) During Electrolysis Mode

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Abstract

Unitized regenerative proton exchange membrane fuel cell (URPEMFC) is one of the most prominent solutions to combat the intermittency nature of renewable energies as it can both generate electricity and perform hydrogen regeneration. However due to this advantage, the cell's sensitivity is increased to cater for oxygen redox reaction during electrolysis. One of the biggest challenges during electrolysis mode is to retain its efficiency. Through past studies, electrolysis mode efficiency increases with increasing temperature. At a highly elevated temperature, material resistance is the biggest constraint in providing a higher electrolysis efficiency. In this paper, a three-dimensional, non-isothermal and multiphase URPEMFC model will be generated to study the electrolysis mode efficiencies during start-up, operational and shutdown sequences. The model is generated using Ansys Fluent through computational fluid dynamics (CFD) where species and temperature profile at the oxygen side electrode is studied. The results revealed that the optimum temperature is different at different operating points. Specifically, the temperature is highly dependent on parameters such as operating pressure and cell voltage which can be calculated. Bubble formation during electrolysis mode start-up disrupts pressure distribution. Furthermore, optimization of pressure and voltage reduces the probability of hydrogen cross-over at low current densities. The optimized parameters increase the rate of oxygen production and reduce pressure drop, at the same time, enhancing water and heat distribution.

Keywords: *unitized regenerative fuel cell; electrolyzer; dynamic response; multiphase*

Influence of Cathode Fabrication Method for Planar Solid Oxide Fuel Cell (SOFC) On Electrochemical Performance Properties: A Review

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Abstract

There is a growing interest in solid oxide fuel cells (SOFC) as an alternative source of green power generation. Anode, electrolyte, and cathode are the basic components of a SOFC. In a single SOFC cell, a dense electrolyte is typically sandwiched between a porous cathode and anode. The fundamental interaction of cathode oxygen oxidation, anode hydrogen reduction, and electrolyte ions transportation contributes to the overall performance of SOFCs. Thus, the contact layer between each porous anode, cathode, and dense electrolyte must be completely cohesive. SOFC application is particularly concerned with a solid construction, either a planar SOFC or a tubular SOFC. In this context, an appropriate fabrication method for a planar SOFC stack is essential for enhancing SOFC reliability and performance. This review presents an overview of fabrication processes, including magnetron sputtering, screen printing, tape casting, dip coating, slurry spin coating, electrophoretic uniaxial pressing, and sol-gel. The paper covers fabrication working principles, advantages and limitations, and additional evaluations of prior work on each fabrication technique parameter. The electrochemical performance of each of the above-mentioned fabrication techniques and how each component can be used in SOFCs are also discussed. It's interesting how different materials result in distinct material properties. Thus, the suitability and compatibility of materials with fabrication parameters are also covered in this study. Briefly summarized, the various fabrication methods for planar SOFC stacks, as well as the overall performance of the created single cells, are the key points of this review work.

Keywords: *cathode; electrochemical; fabrication method; planar SOFC; single cell*

Rounded Trapezoidal Flow Channels Used in Polymer Electrolyte Fuel Cells: A Parametric Numerical Study

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Abstract

Metallic flow field plates have been increasingly used in polymer electrolyte fuel cells (PEFCs) and this is mainly due to ease of manufacturing (compared to graphite plates) that allows for cost-effective mass production. Forming processes (e.g., stamping) are normally used to manufacture the metallic plates. The requirement of the forming process results in flow channels with rounded trapezoidal cross-sections. However, most of the PEFC mathematical models assume that the flow channels are rectangular, which is not the case when using metallic sheets for flow-field plates. This assumption may lead to inaccurate predictions. Therefore, the objectives of this study are to (i) solve fully developed laminar flow in rounded trapezoidal flow channels, (ii) investigate the impact of the geometrical properties of these channels (e.g., the sidewall angle) on the flow and thermal characteristics (e.g. the Poiseuille number) and (iii) assess the inaccuracy when assuming equivalent rectangular channels.

Keywords: *polymer electrolyte fuel cells; trapezoidal flow channels; rounded corners*

Effect of Copper Oxide on the Performance of Ni-Cu-Based Anode in Solid Oxide Fuel Cells Operated on Biogas Fuel

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Abstract

This research paper focuses on the development and testing of a nickel-based anode with and without the addition of copper oxide. The anode and LSCF-based cathode are screen-printed onto an electrolyte-supported cell, which is fabricated using water-based tape casting. The completed single cell is then tested using simulated biogas fuel with varying compositions of methane and carbon dioxide. The performance of the cell is evaluated through open circuit voltage (OCV) and power density measurements. The results of the tests show that the addition of copper oxide to the nickel-based anode can improve the performance of the cell, particularly under lower methane concentrations. The cell with a copper oxide composition of 20% by weight showed the highest power density and OCV under various biogas compositions. Carbon deposition analysis and post-mortem analysis of the tested cell were also conducted to evaluate the long-term stability and potential degradation of the cell. The results show that the addition of copper oxide to the nickel-based anode can reduce the carbon deposition on the anode surface and improve the stability of the cell. Overall, the findings of this research suggest that the use of a nickel-based anode with a certain composition of copper oxide can improve the performance and stability of solid oxide fuel cells (SOFCs) operating on biogas fuel. The use of water-based tape casting to fabricate the cell also demonstrates a cost-effective and scalable method for SOFC production. These results could have important implications for the development and optimization of SOFCs for clean energy applications.

Keywords: *biogas-fuelled SOFC; copper-based anode; carbon deposition; water-based tape casting; biogas composition*

An Overview of Hydrogen Potential in Decarbonization Towards Green Steel Ecosystem

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Abstract

The iron and steel (I&S) sector are among the largest industrial consumer of coal in the world. In Malaysia, coal is consumed extensively for power generation and in two energy-intensive industries: cement, and iron & steel industry. Today, about 70% of the steel produced uses coal as metallurgical coke for iron ore reduction and fuel for heating. It is estimated that every ton of steel produced emits approximately 1.85 t of carbon dioxide, which contributes approximately 7% (~2.6 Gt) of global carbon dioxide emissions annually. There is an urgent need to reduce the carbon emissions of the I&S sector, or the industry will have to pay for a heavy carbon tax not just domestically, but internationally, and a possible risk of product export restriction, if continue with business as usual. In addition, financial institutions are expected to factor in the climate-related financial risks and charged a higher lending rate to the high-emitting sector with poor environmental-social-governance (ESG) ratings. Green and affordable hydrogen could be a sustainable potential solution to substitute coal as burning fuel and reducing agent. This review discusses hydrogen technologies, how hydrogen can decarbonize steel production, a preliminary feasibility study for hydrogen as a substitution to coal, the relationship of hydrogen with the ESG of a company and concludes with how hydrogen helps to maintain the sustainability of economic, social, and environmental perspectives. These outputs are expected to provide a possible solution for the government and industry to accelerate green initiatives, as targeted in the 12th Malaysia Plan.

Keywords: *hydrogen; decarbonization; direct reduction iron; green steel*

The Innovation of Flow Field Configuration for Proton Exchange Membrane (PEM) Fuel Cell and Electrolyser

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Abstract

A hydrogen Proton Exchange Membrane (PEM) fuel cell and electrolyser channel configuration is essential to its optimal operation and overall effectiveness. The following are the main reasons in support of channel configuration. The distribution of water, hydrogen and oxygen gases to the electrodes is determined by the channel configuration, which is essential for effective reaction and electric generation. Additionally, the channels must be designed to efficiently manage the water generated by the reaction, to avoid floods and provide proper functioning. Besides, an efficient cooling system must be supported by the channel configuration to control the fuel cell temperature and prevent thermal damage. To increase reaction rates and promote efficient catalyst utilization, the channel configuration requires adequate contact of the catalyst to the water and gases. To maintain the PEM stability and durability, the channel configuration must protect it against mechanical damage and ensure sufficient hydration. Furthermore, the performance and durability of hydrogen PEM fuel cells and electrolyser are greatly enhanced by a well-designed channel configuration, and careful consideration of the aforementioned criteria is necessary for the optimal design. The serpentine configuration, parallel configuration, wave-like configuration, tree-like configuration, adding blockage, and many other configurations will be covered in this paper.

Keywords: *channel configuration; hydrogen; fuel cell; electrolyser*

Effect of Different Fibrous Silica Metal Oxide Photoanodes for Enhanced Photoelectrochemical Water Splitting

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Abstract

Utilization of photoelectrochemical (PEC) water splitting to harvest intermittent solar sources as hydrogen is an enticing potential solution to energy and environmental difficulties. However, the actual applicability is severely limited by the low solar conversion efficiency due to low charge carrier separation efficiency. Herein, fibrous silica-titania (FST) and fibrous silica tantalum (FSTa) photoanode for PEC water splitting was synthesized using the microemulsion method reported in this study. The physicochemical and electrical properties of the photoanodes were investigated using XRD, UV-Vis DRS, FTIR and EIS Nyquist Plot. FST had a higher photocurrent density of 13.8 mA/cm² at 1.23 V_{RHE} and a higher solar-to-hydrogen (STH) efficiency of 16.9% when compared to commercial FSTa with 9 mA/cm² and STH of 11.1%. This is due to the better crystallinity, higher Si-metal interaction, and lower electron-hole recombination rate of the FST photoanode. Fibrous silica-based photoanodes fabrication revealed significant insights into the development of high-performance photoanodes for enhanced PEC water splitting.

Keywords: *Fibrous silica; photoelectrochemical water splitting; titania; tantalum; hydrogen Production*

Annealing Effect on the Structural and Photoelectrochemical Performance of MoS₂/Ni₃S₂/ZnO/Graphene/Nickel Foam

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Abstract

A comparative study of the annealing process influence on the photoelectrochemical (PEC) performances of ZnO/graphene/nickel foam (NF) and MoS₂/Ni₃S₂/ZnO/graphene/NF, as grown by simple two-step hydrothermal method is presented. First, vertically aligned ZnO nanorods (NRs) on graphene/nickel foam were synthesized by hydrothermal method at low temperature, followed by MoS₂/Ni₃S₂ deposition on ZnO/graphene/NF. The as deposited heterostructures were then annealed at different environments [air and hydrogen/argon (H₂/Ar) gas] at 450°C for one hour to improve the material properties. To determine the structural properties of ZnO/graphene/NF and MoS₂/Ni₃S₂/ZnO/graphene/NF, field emission scanning electron microscope (FESEM) and X-ray diffraction (XRD) were analysed. XRD result has confirmed the formation of hexagonal wurtzite ZnO structure, MoS₂, Ni₃S₂, graphene, and NF. The FESEM revealed the formation of nanorods on the ZnO surface and spherical shapes on MoS₂/Ni₃S₂/ZnO surface. The morphologies of the materials are maintained, whereas the coverage area of ZnO nanorods and spherical shapes of MoS₂/Ni₃S₂/ZnO/graphene/NF has been improved after the annealing process using H₂/Ar gas. However, the use of H₂/Ar gas in the annealing environment shows an increase in the diameters of nanorods and spherical shapes, as opposed to using an air environment. The samples were then tested for PEC water splitting and the results show that the photocurrent performance using an air environment was found to be higher than that of H₂/Ar gas environment, which are 101.52 mA/cm² and 262.99 mA/cm² for ZnO/graphene/NF and MoS₂/Ni₃S₂/ZnO/graphene/NF, respectively. Thus, our results demonstrate that the annealing environment gives a significant influence where the higher performance of PEC water splitting can be obtained with low diameters of the photoelectrode after the annealing process using an air environment.

Keywords: ZnO; MoS₂; Ni₃S₂; Annealing process; PEC water splitting

From Noble Metals to Nickel-Iron-Based Oxides (NiFeO_x) Electrocatalyst: A Review of Emerging Electrocatalyst for Oxygen Evolution Reaction (OER) under Alkaline Conditions

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Abstract

The development of efficient and environmentally friendly fuels is crucial due to the severity of the energy crisis and the environmental effects of global anthropogenic activity. One alternative fuel that has gained interest is hydrogen, which can be produced sustainably through water electrolysis and with little harm to the environment. However, the slow oxygen evolution reaction (OER) at the anode has hindered the widespread use of water-splitting technology. This has led to the search for high-performance electrocatalysts for enhanced energy conversion efficiency in OER. The most promising earth-abundant OER catalysts, besides noble-metal-based catalysts such as IrO₂ and RuO₂, are nickel iron-based oxides (NiFeO_x). These oxides are of interest due to their high catalytic activity. This review starts with a brief explanation of the OER mechanism and how electrons work together in an alkaline medium to form an oxygen molecule. The recent advancements in NiFeO_x preparation methods, morphology, and stability are then further examined to elucidate their rising catalytic activity. Finally, a discussion of the challenges and potential of a NiFeO_x catalyst for OER is presented.

Keywords: *OER electrocatalyst; nickel-iron-based oxide (NiFeO_x) catalyst; water-splitting*

Noble Metal Catalysts for Hydrogenation and Dehydrogenation of Liquid Organic Hydrogen Carriers (LOHCs): A Review

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Abstract

Hydrogen refuelling stations require hydrogen at a very high pressure of 700 bar. Currently, most of the refuelling stations use conventional mechanical compressors for compression. Conventional compressors require high maintenance, consume electrical power, and are more costly and unsafe. On the other hand, metal hydride compressors can counter these disadvantages and showcase additional merits such as the ability to work on low-grade thermal energy. The present work investigates the prospects of minimizing the high compression costs of hydrogen (around 48% of the total capital cost of the refuelling station) by using a hybrid compressor based on metal hydride technology. The hybrid compressor is designed in such a way that the initial compression stage up to 500 bar is facilitated by a metal hydride compressor followed by the second stage which will elevate the pressure up to 1000 bar. Moreover, a comparative energy assessment of the hybrid and conventional compressors is carried out. The study will also focus on the economic assessment of hybrid and mechanical compressors. The results from the present research work will help in designing more efficient and environmentally friendly compression systems for hydrogen refuelling stations.

Keywords: *Hydrogen Refuelling Station; Hybrid Compressors; Metal Hydride Compressor*

Gasification Reaction on CeO₂ (111) and Effects on the Structural and Electronic Properties of Adsorption Molecules

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Abstract

The production of hydrogen (H₂) from biomass gasification offers exceptional benefits regarding renewable energy sources, zero-carbon emission, cost-effective processes, and high efficiency. The addition of catalysts to biomass gasification could accelerate the process and minimize the formation of coke. However, the catalyst deactivation caused by carbon deposition, poisoning, and sintering is still a significant problem in the gasification process. Therefore, achieving sustainable exploitation of the renewable natural resource of biomass requires substantial development and optimization of the present gasification process. The efficiency of gasification might decrease because of such a process. In this study, CeO₂ (111) is chosen and characterized using X-ray diffraction analysis, BET surface area analysis, transmission electron microscopy and field-emission scanning electron microscopy. The reaction mechanism of the catalytic gasification was investigated using density functional theory. Three catalyst models, CeO₂ (111), Zr-CeO₂ (111) and Ni-CeO₂ (111) have been studied in this work in terms of structural, electronic, and adsorption molecules properties through density functional theory (DFT) studies. The structural and electronic properties of the modified catalyst model show the ligand and strain effect on the alloy with the addition of Zr and Ni as second metal promotes the adsorption capability; however, the catalytic activity heavily depends on the atom composition. Searching for active sites is also carried out by adsorption of selected atoms and molecules and used as a preliminary study to find possible active sites for gasification reactions. The Zr-CeO₂ (111) and Ni-CeO₂ catalyst exhibits better adsorption ability on atomics, simple molecules such as carbon monoxide, carbon dioxide and hydrogen gas. The Zr and Ni metal is a suitable second metal candidates for the catalyst to proceed with the gasification reaction and simultaneously reduce carbon deposition, poisoning, and sintering problems.

Keywords: *catalyst; Cerium (IV) oxide; density functional theory*

Improved Performance of Copper Based Photoelectrode with Underlayer for Photoelectrochemical Water Splitting

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Abstract

Copper (I) oxide, often known as Cu₂O, has a strong reputation for being a promising photocathode for the photoelectrochemical (PEC) water splitting. Copper (Cu), on the other hand, is an inexpensive metal that has the potential to operate as a substitute for the noble metal catalysts. However, the main challenge of Cu₂O is its low solar to hydrogen (STH) energy conversion. The Cu₂O underlayer modification is comprehended to enhance PEC performance of the Cu₂O as it may improve the photogenerated hole sweeping rate for an efficient H₂ production. In this study, Cu underlayer was electrodeposited prior Cu₂O electrodeposition on blank FTO to study the influence of underlayer towards the performance of the Cu₂O. To investigate the influence of electrodeposition parameters on the Cu₂O photocatalytic performance, the electrodeposition time for the Cu underlayer was subject to a range of changes. Meanwhile, for Cu₂O electrodeposition, the parameters were kept constant to serve as the variable control. The structural properties of Cu₂O photoelectrode, with and without Cu underlayer, were determined via field emission scanning electron microscopy (FESEM), and X-ray diffraction (XRD). The XRD analysis confirmed the presence of Cu₂O, and Cu. Meanwhile, the FESEM analysis revealed the formation of face-raised cubes of Cu₂O and compact Cu underlayer on the FTO surface. The photoelectrode with Cu underlayer exhibits a photocurrent density that is 1.6 times higher than without Cu underlayer under simulated sunlight. Consequently, this study provides a promising insight of Cu₂O photoelectrode for PEC water splitting.

Keywords: *copper oxide; underlayer; electrodeposition*

Electrocatalytic Hydrogen Evolution Reaction of Binder-Free NiMo for Alkaline Water Splitting

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Abstract

Electrocatalytic water splitting in the alkaline electrolyte is able to generate high-purity H₂ for use as fuel and other commercial applications. However, to date, the HER activity of the majority of TM-based electrocatalysts is more limited compared to the benchmark Pt/C. The use of binders such as Nafion during electrode preparations may also inhibit the electrocatalytic activity through the blockage of active sites. Therefore, this work focuses on the direct growth of electrocatalytic material on a conductive nickel foam (NF) substrate without binders. Nickel-molybdenum (NiMo) alloy is grown on the NF substrate through a facile one-pot hydrothermal reaction followed by thermal annealing. NiMo/NF electrodes are characterized in terms of their crystallography, morphology and electrocatalytic HER activity. A change in the morphology of the electrocatalyst was observed upon changing the concentration of Mo, which affects the resulting electrocatalytic activity. Half-cell HER analysis in 1 M KOH has determined that the NiMo/NF-1:1.5 shows the smallest overpotential at 10 mA/cm². Improvement in the HER activity can be attributed to the mixed morphology of nanofibers and nanoparticles in NiMo/NF-1:1.5 that may affect the exposed active sites. Strong adhesion of NiMo on the NF substrate also facilitates electron transfer between catalyst and electrode. Hence, the NiMo/NF electrode shows excellent potential as a TM-based electrocatalyst for alkaline HER.

Keywords: *electrocatalyst; transition metals; hydrogen evolution reaction*

Development of New Hydrogen Storage Material: Metalorganic Hydride (Li-phenoxide)

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Abstract

Arene-cycloalkane pairs has been recognized as one of the best candidates in organic hydrides for hydrogen storage application. However, this organic hydride possesses typically unfavourable thermodynamic and kinetic in hydrogenation and dehydrogenation. Recently, thermodynamic modification via introduction of electron donating alkali and alkaline earth metals into the arene-cycloalkane pairs was proposed as a new strategy for circumventing thermodynamic constraint. Herein, the mono-metallic replacement of H in the –OH group of this arene-cycloalkane pairs (phenol-cyclohexanol) was synthesized using a simple wet synthesis method with Li precursor. The successful metalation is evident through conspicuous disappearance of hydroxyl group (-OH) which previously existed in the phenol compound. It is worth mentioning that the X-ray diffraction characterization confirms the presence of a new crystal structure. The potential of using this new metalorganic hydride for vehicular hydrogen storage was also evaluated by means of its hydrogen uptake and release properties.

Keywords: phenoxide; organic hydride; metalation; hydrogen storage; hydrogen energy

Study of Metal-doped X-Ni/CeO₂ (X= Zr, La, Sr) Catalysis Activity for High H₂ Production from Dry Reforming Methane

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Abstract

The quest for producing high amounts of hydrogen to support the renewable energy ecosystem motivates the development of high-performance heterogeneous catalysts with low carbon deposition for use in dry methane reforming. The objective is to optimize the metal loading of the support and promoter to create a more efficient catalyst. Firstly, the molar ratio of NiCeO₂ support catalyst was varied from 0.05, 0.2, 0.3, 0.4, and 0.5 and tested in the dry methane reforming reaction. It was found that the NiCeO₂ support with a molar ratio of 0.4 gave the highest H₂ production with a yield of 69%. Then, this optimum support composition of NiCeO₂ (molar ratio 0.4) was further doped with Zr, La, and Sr metals as promoters. The morphology, chemical composition, and structure of the catalysts were characterized by scanning electron microscopy (SEM), X-ray diffraction (XRD), transmission electron microscopy (TEM), Brunauer–Emmett–Teller (BET), and X-ray photoelectron spectroscopy (XPS). Based on the results, it was discovered that NiCeO₂ (molar ratio 0.4) doped with Zr (2 wt.%) is better than NiCeO₂ (molar ratio 0.4) doped with La (2 wt.%) and NiCeO₂ (molar ratio 0.4) doped with Sr (2 wt.%) with an 86.5% hydrogen yield, 89% CH₄ conversion, and 81.2% CO₂ conversion.

Keywords: *dry reforming methane; nanocatalyst; hydrogen yield*

Design and Implementation of Portable Thermoelectric Generator

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Abstract

This paper presents the implementation and design of a thermoelectric generator (TEG) portable system for generating electricity from heat sources. The relevance of implementing and generating electricity this way is that its clean energy, and it depends on the capture of losses with an advantage of being portable. There are many residual heat energies from various heat sources that is released to the environment without utilizing its potential. With the proposed device, the heat energy will not go to waste, and instead, it will be used for electric generation, which is useful for specific individuals such as campers or hikers, and people that lives off the grid. The characterization of TEGs that are used have been measured to gather the data for voltage, current, and temperature, in real-time, for temperatures down to 125 °C without signal degradation.

Keywords: *TEG; temperature difference; seebeck effect; seebeck coefficient*

Wet Torrefaction of Palm Oil Mill Effluent as an Emerging Technology for Biohydrogen Production: An Optimization Study

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Abstract

With the current global energy transition, renewable and clean energy are receiving attention as the alternative approach towards sustainable and net-zero carbon development. Wet torrefaction is an emerging thermochemical conversion technology that can enhance the properties of wet biomass, making it suitable for various applications such as alternative fuel and bioenergy generation. The utilization of palm oil mill effluent waste towards the production of renewable bioenergy such as biohydrogen possesses a potential environmentally sustainable approach for palm oil industry application. The integration of energy informatics through optimization study on the wet torrefaction pretreatment of palm oil mill effluent is carried out under several operating conditions such as temperature, holding time and biomass-to-water concentration, using Box-Behnken response surface methodology to determine the optimum conditions for biomass properties enhancement towards biohydrogen production. The torrefied palm oil mill effluent is further characterized to investigate the potential biohydrogen production using dark fermentation. The study shows that the wet torrefaction pretreatment with the operating temperature of 180 °C, holding time of 10 min and around 70% of biomass-to-water percentage is the optimum condition to produce a maximum concentration of around 3.9 g/L total reducing sugar with a maximum of around 77% chemical oxygen demand (COD) removal efficiency. Furthermore, wet torrefaction could improve the liquid efficiency where subsequent dark fermentation batch study utilizing the substrates will be carried out to determine the biohydrogen production.

Keywords: Wet torrefaction; biohydrogen; energy

Anaerobic Mono-Digestion of Chicken Manure: Performance Analysis and Optimization for Biogas Yield

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Abstract

Chicken manure (CM) produces a strong and unpleasant odour due to sulphur and ammonia compounds, which can create nuisance and environmental concerns, especially in large-scale farming operations. Therefore, optimization of different temperatures and substrate ratios for biomethane production from mono-digestion of CM at initial chemical oxygen demand (COD) and total solids (TS) of 92.5 g/L and 31.36%, respectively, was conducted at a laboratory scale using automatic methane potential test system (AMPTS II) to maximize the efficiency and yield of biogas from the CM. In this study, the initial observation shows that a substrate-water ratio of 1:1 gives the highest biomethane production and yield after 12 days of retention time at an optimum temperature of 37 °C. These initial hypotheses prove that temperature and retention time is crucial to ensure process stability and optimal biomethane production. Utilizing CM for biogas production, primarily on-site, could meet the energy demands of the poultry farm or be injected into the natural gas grid. Mono-digestion of CM could reduce the methane emissions from its natural decomposition, thus reducing its environmental impact and potential pollution risks.

Keywords: *chicken manure; energy; anaerobic digestion; mono digestion; biomethane*

Game-based Learning for Fuel Cell Education in Malaysia

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Abstract

The need to understand fuel cell education is now crucial as exposure to the fuel cell can create a future economy, and human capital needed and create environmental awareness as a fuel cell is the future green technology. This can be conveyed through an educational program which enables a meaningful and more transparent process of knowledge transfer. This paper provides an overview of the need to educate our students, as future fuel cell users and designers, towards the widespread acceptance and implementation of hydrogen fuel cell technology. Game-based learning has the potential to provide an engaging and motivating learning process with the digital mobile game as an effective tool in facilitating fuel cell education. Game-based learning has been found to improve cognitive development and learning experiences and promote learning engagement and motivation with the help of various game design elements. The findings from this study support further development of a fuel cell education module that is suitable for secondary students using digital mobile games as a learning tool.

Keywords: *fuel cell education; mobile games; game-based learning*

The Roles of rGO in Enhancing ZnOFe₂O₃ Performances for the Glucose Oxidation Evaluation

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Abstract

The hybridization of metal oxides has been shown to contribute to a rapid electron transfer rate, a large surface area, and high electrocatalytic activity in electrochemical oxidation materials. In this study, Zinc Oxide (ZnO) doped with Iron Oxide (Fe₂O₃) was dispersed on Reduced Graphene Oxide (RGO) to form a ZnOFe₂O₃/rGO hybrid using a simple one-step hydrothermal method for glucose oxidation. The synthesized ZnOFe₂O₃/rGO composite was characterized by Field Emission Scanning Electron Microscopy, Fourier Transform Infrared Spectroscopy, and X-ray Diffraction analysis. The effect of rGO in improving ZnOFe₂O₃ electrochemical performance was evaluated using cyclic voltammetry (CV). The hierarchical nanostructures demonstrated significantly improved catalytic performance for glucose electrooxidation, with an open circuit potential positively shifted to 530 mV vs. Ag/AgCl, making them suitable electrocatalysts for use as anodes in glucose fuel cells. The maximum current density of $1.90 \times 10^{-1} \text{ mA cm}^{-2}$ was achieved in the electrochemical glucose oxidation equipped with ZnOFe₂O₃/rGO, which was approximately 28 and 4.61 times higher than ZnO ($6.82 \times 10^{-3} \text{ mA cm}^{-2}$) and Fe₂O₃ ($4.12 \times 10^{-1} \text{ mA cm}^{-2}$), respectively. Hence, a combination of Fe₂O₃ and rGO is believed to play a crucial role as an electrocatalytic mediator in facilitating charge transfer for glucose oxidation.

Keywords: *electrochemical; glucose oxidation; metal oxide*

Rheology Properties in Composite Filament Making

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Abstract

The use of 3D printing is becoming increasingly widespread across industries, allowing to produce a variety of open-source designs. This widespread use indirectly attracts the interest of researchers to study and explore new materials that can be used and applied in the manufacture of these additives or 3D printing. The materials resulting from such studies serve as feed material for examining the physical properties of a product. This study utilized Polyamide reinforced carbon fibre composites to investigate their rheological properties in the production of composite filaments before using them as 3D printing feed material with the use of deposition modelling (FDM) method. The process involves heating the polymer filament using a hot nozzle to ensure that the semi-flow material is extruded for printing. The material partially flows out of the nozzle and is then upheld into a thin layer. To achieve success, two primary methods were used: optimizing rheological parameters through carbon fibre reinforced polyamide and studying the physical properties of carbon fibre reinforced polyamide composite materials with a 40% carbon fibre composition. The use of the RSM method confirmed that the addition of applied load contributes to the viscosity of PACF composite feed material.

Keywords: *carbon fibre; polyamide; viscosity; shear rate; temperature; load*

Advances in Microbial Electrochemical Technologies for Sustainable Wastewater Treatment, Desalination, Hydrogen Production, and Biosensors: From Laboratory Insights to Field Applications

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Abstract

This abstract presents groundbreaking microbial electrochemical technology research with transformative potential across wastewater treatment, desalination, hydrogen production, and innovative sensing. Collaborative efforts drive these studies, merging microbiology, electrochemistry, and engineering for environmental preservation and sustainable energy. A key achievement involves Microbial Electrodialysis Cells (MEDCs) with proton pathways, revolutionizing energy recovery from wastewater, offering desalination and hydrogen production. Microbial fuel cell-based sensors enhance hydrogen production via metabolic monitoring of *Enterobacter* sp. KBH6958, revealing pH and glucose effects. Optimizing hydrogen production through anode-fed-batch and controlled voltage advances microbial electrolysis. Microorganisms' catalytic abilities are harnessed for eco-friendly energy production through enhanced reactions. Research covers zinc removal via microbial fuel cells and modified gas diffusion electrodes for efficient CO₂ conversion. Applications extend to material screening, biosensor development, and wastewater monitoring, promoting resource recovery and greenhouse gas mitigation. Challenges and strategies for applying microbial desalination cells in real-world settings are addressed. Continuous modes elevate CO₂ bio-production via microbial electrosynthesis. The abstract underscores recent strides in microbial electrochemical tech, emphasizing sustainable solutions for global challenges—wastewater treatment, desalination, clean energy.

Keywords: *microbial electrochemical technologies; wastewater treatment; hydrogen production; desalination; biosensor*

Polylactic Acid /Graphene Nanoplatelets Conductive Polymer Composites: Mechanical, Thermal and Electrical Properties

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Abstract

This study investigates the performance of conductive polymer composites (CPC) composed of conductive filler, graphene nanoplatelets (GNP) which dispersed in insulative polymer matrix, polylactic acid (PLA). The GNP were added into PLA at various loadings (1, 3, 7 and 12 wt%) and melt blended via internal mixer to produce CPC. The hot press machine was then used to compress the CPC into thin sheet for characterization. Results showed that addition of GNP at 7 wt% can bring the CPC to become electrically conductive ($\sim 10^4$ ohm). The tensile modulus increased with the addition of GNP, but opposite trend was observed in elongation at break and tensile strength. The addition of GNP also improved the thermal stability as reflected in higher onset degradation temperature.

Keywords: *graphene nanoplatelets; polylactic acid; conductive polymer composites*

Electronic Properties of a Single and Holey Multilayer Graphene

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Abstract

Recent development of Graphene in industries and research intriguing research on its benefits for catalyst support, especially in fuel cells. Mostly, the problem found in graphene is how it can hold the catalyst at the optimal number so that the reduction reaction at the cathode happens quickly. This paper is intended to study the electronic properties of single and holey multi-layer graphene, and its application for fuel cell's electrode components, in terms of surface area and conductivity related to the DFT concept. By using Materials Studio 2016 software, Graphene, and holey multilayer Graphene were built manually (P63/MMC space group lattice with lattice parameter $a = 2.470 \text{ \AA}$, $b = 2.470 \text{ \AA}$, $c = 1.930 \text{ \AA}$, lattice angle $\alpha = 90^\circ$, $\beta = 90^\circ$, $\gamma = 120^\circ$ and supercell of $3 \times 3 \times 1$ for single-layer graphene and $3 \times 3 \times 3$ for multilayer holey graphene with some C atom were removed). The band structure, density of states, partial density of states, molecular dynamics, and electron density was calculated by using the GGA-PBE function in the CASTEP package provided by the software. The results show that the holey multilayer graphene has better electronic properties (exhibits more conductivity) for the fuel cell's electrode application.

Keywords: *graphene; electronic properties; DFT*

Synthesis, Characterization and Photocatalytic Activities of Silver Doped Zinc Oxide Nanoparticles Towards Photodegradation of Endosulfan

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Abstract

Endosulfan is an organochlorine pesticide that can contribute to environmental toxicity, making it crucial to ensure its removal. In this study, zinc oxide nanoparticles (ZnO-NPs) and silver-doped zinc oxide nanoparticles (Ag/ZnO-NPs) were synthesized via a self-propagating combustion (SPC) method using triethanolamine as fuel and calcined at 700 °C. This low-cost and simple method produces uniform powder and has the advantage of time and energy efficiency. Ag/ZnO-NPs were utilized in photocatalysis due to their non-toxicity, affordability, and ability to reduce band gap energy, which results in high photocatalytic activity by increasing surface defects with the presence of silver metal. The efficiency of a photocatalyst can be improved by reducing the electron-hole pair's recombination rate. X-ray diffraction analysis confirmed that the ZnO sample was pure and single-phase, while Ag/ZnO-NPs samples showed the presence of additional Ag diffraction peaks. From scanning electron micrographs, the crystallite size of ZnO-NPs decreased with the presence of the dopant. The band gap energy obtained for all the Ag/ZnO-NPs samples was in the range of 3.39–3.30 eV, which was lower than the parent ZnO-NPs' value of 3.40 eV. In this study, photocatalytic degradation of endosulfan was found to be 69.1% using 7% Ag/ZnO-NPs, which was better than pure ZnO, which showed only 38% degradation after 3 hours of reaction. This was attributed to the presence of Ag with a smaller size and lower band gap, which can enhance surface area, promote electron-hole separation, and decelerate charge carrier recombination.

Keywords: *endosulfan; cathode; photocatalyst; combustion; Ag/ZnO-NPs; Ag doped ZnO-NPs*

Efficient Microwave Irradiation-Assisted Synthesis of PtSn Bimetallic Alloy for Enhancing Methanol Oxidation Reaction

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Abstract

The shift to green energy sources is more important than ever before to reduce our reliance on fossil fuels and protect the planet. In pursuit of creating an alternative power system for a sustainable future, direct methanol fuel cells (DMFC) notch up as a clean power source to fight against climate change. Integrating DMFC into the worldwide power system would propel the achievement of many Sustainable Development Goals (SDGs). However, this type of fuel cell relies heavily on its electrocatalyst counterpart. Electro-catalysts based on Pt alloyed with transition metals have emerged as promising candidates for enhancing the performance of DMFC. This work introduces PtSn as a catalyst that was synthesised using a microwave irradiation technique at different synthesis times ranging from 40 s to 210 s. TEM result shows agglomerated cubic nanoparticles when irradiated for 40 to 150 seconds, while a mix of spherical and hexagonal structures was observed for samples synthesised at 150 s and above. The average particle size is between 5 nm to 15 nm. To further confirm the formation of the PtSn surface alloy, XPS was used to analyse the 180 s sample. The photoelectron peaks of the PtSn samples show a shift towards lower binding energies when compared to a pure Pt reference obtained from the literature. The nature of this shift can be explained by the formation of an alloy between the deposited Pt and Sn. The sample also showed excellent catalytic performance for the oxidation of methanol in an acidic electrolyte, with better resistance to CO poisoning than PtSn synthesised for 40 s.

Keywords: *PtSn; microwave-assisted; nanoparticles; reaction times*

Formulations of Copper-Tin Oxide Derived Catalysts for Electrochemical CO₂ Reduction in Microbial Electrosynthesis Cells

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Abstract

The reduction of carbon dioxide to formate is one of the primary products in microbial electrosynthesis systems (MSCs). However, this process still has low efficiency due to the catalyst's low selectivity, which leads to the formation of side products and hinders formate formation by promoting hydrogen evolution reaction (HER). This study aims to find a better cathode catalyst as a composite electrode without noble metals. To achieve this, we created a copper-tin (Cu-Sn) cathode using the electrodeposition method, which is a widely used conventional and cost-efficient method. Copper is considered a material with good selectivity in reducing CO₂ to formate and, with a lower cost, is an excellent candidate for this experiment. The experiment yielded a uniformly good deposition coating, as indicated by several reduction peaks during the CV test. Surface morphology under FESEM-EDX suggests the distribution of Cu and Sn on the carbon cloth surface in the form of a crystallized cluster. The modified cathode also showed improvement in generating a higher current, with 64.44 mA/cm² as compared to the unmodified cathode at 60 mA/cm², suggesting better biocompatibility and greater electron transfer between the microbes and the cathode.

Keywords: CO₂ reduction; microbial electrosynthesis; biocathode modifications

Study the Effect of Ti and Al Doping in NMC 111 to Improve Structural Stability and Electrochemical Performance of Li-Ion Batteries

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Abstract

Element doping has been testified to be one of the strategies to enhance the battery's performance. In this paper, the Ti and Al-doped in $\text{LiNi}_{1/3}\text{Mn}_{1/3}\text{Co}_{1/3}\text{O}_2$ (NMC 111) cathode material has been successfully prepared by the combustion method. The resulting material combines the advantages of Ti-doped, which can effectively improve structural stability, lowering the cation mixing and providing a larger surface area with a smaller crystallite size compared with pristine NMC 111 and Al-doped. Electrochemical performance evaluation revealed that NMCT delivered a high initial discharge capacity of 148.55 mAhg^{-1} at 3 C and lower capacity retention of 7.32 % after 30 cycles. The optimization of NMCT materials annealed at various temperatures for 48 hours shows that the resulting temperature of 800°C is the optimum condition that can promote good electrochemical performance. In conclusion, the cation doping strategy has been demonstrated to be a great promise for stabilizing the structure and improving the electrochemical performance in lithium-ion batteries application.

Keywords: Lithium-ion Battery; Cathode; Doping; Combustion; NMC 111

Optimization of URPEMFC Bipolar Plate Surface Coating Through the Understanding of Corrosion Mechanism

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Abstract

A unitized regenerative proton exchange membrane fuel cell (URPEMFC) is an efficient system incorporating fuel cell and electrolyzer operation into the same cell stack. It opens the possibility of hydrogen production and power generation within a simple form factor allowing for more flexibility in application. One of the main challenges with the system still stands with its tendency to be subject to severe corrosion under its harsh working conditions. The bipolar plate is the component that contributes to the majority of the stack weight and cost needed to be able to withstand the system requirements for long-term operation efficiently. This study presents the option of utilizing computational fluid dynamic (CFD) simulation as the method to explore the suitable bipolar plate material and corrosion-resistant surface coating. The electrochemical reaction of the corrosion stemming from the URPEMFC operating condition will be simulated between the switching of the fuel cell and electrolyzer mode. As a result, the electrochemical corrosion parameter, such as corrosion current density and rate of corrosion obtain from the simulation result, measure the corrosion-resistant properties of the surface coating. The corrosion rate integrates into the moving mesh of the surface coating domain and then reflects the changes on the surface topology. This method proves to be an effective solution while also offering the flexibility to identify the effect of the URPEMFC operating requirement contributing to the system degradation.

Keywords: surface coating; corrosion; computational fluid dynamic

Catalytic Hydrogenolysis of Sorbitol over Chromium Alumina Catalyst

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Abstract

Sorbitol generated from cellulose is developing as a viable and renewable feedstock for the synthesis of value-added compounds. This sorbitol selective hydrogenolysis into ethylene and propylene glycol offers a practical and sustainable way of producing the two glycols. For sorbitol hydrogenolysis, a catalyst that is both highly active and stable is required. Herein, 12wt%Cr₂O₃-AlO₂O₃ was successfully prepared by impregnation method. Characterization of this catalyst by N₂ physisorption, Fourier-Transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) revealed that Cr particles were deposited on the alumina surfaces with close contact and strong interaction. At nearly 64% sorbitol conversion, a combined selectivity of 52.8% to ethylene glycol and propylene glycol was obtained on 12wt% Cr₂O₃-AlO₂O₃. It is discovered that sorbitol hydrogenolysis begins with dehydrogenation and progresses to C–C cleavage via retro-aldolization to create smaller molecules (C₂–C₄). Dehydration, rearrangement, and C–O cleavage of those smaller intermediates result in the formation of C₂–C₃ acids, glycols, and linear alcohols as end products, which is very similar to the chemistry of glycerol conversion.

Keywords: sorbitol; hydrogenolysis; glycols

Progress and Prospects of Solid Oxide Electrolyzer Cells for Hydrogen Production: Opportunities and Challenges

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Abstract

The global energy sector faces significant challenges to achieve net-zero emissions by 2050 to limit global temperature rise to 1.5°C. One potential solution is the use of solid oxide cells (SOCs), a ceramic device with the dual functionality of solid oxide fuel cells (SOFCs) and solid oxide electrolysis cells (SOECs), which can convert the chemical energy of fuels like H₂, natural gas, and other hydrocarbons to electricity and store renewable electric energy from sources such as wind and solar power in the form of hydrogen fuel. SOCs are a promising technology due to their high operating temperature, low material cost, high efficiency, and fuel flexibility. This critical review discusses the potential of solid oxide cells (SOCs) to contribute to the decarbonization of hard-to-electrify sectors and the challenges associated with scaling up their production to meet net-zero CO₂ emissions targets. This review provides an overview of SOCs, including their working principles and thermodynamics, and discusses the key materials and electrode modification methods used in SOCs. Furthermore, this review examines the potential of SOCs to produce green H₂ using renewable energy sources, particularly in the context of water electrolysis. High-temperature solid oxide electrolysis cells (HT-SOECs) can achieve significant reductions in electricity consumption and maybe a more cost-effective route for H₂ production than low-temperature electrolysis. Overall, this review article focuses on SOEC technology and explores the various opportunities to produce green H₂, highlighting its advantages and challenges. SOEC technology is a promising pathway to produce green H₂ for decarbonizing hard-to-electrify sectors. However, achieving the required level of production to achieve net-zero emissions by 2050 remains a challenge that requires sustained investment, innovation, and deployment of renewable energy technologies.

Keywords: water electrolysis; solid oxide electrolysis cells; hydrogen production; green hydrogen; hydrogen economy

Impact of 2-Methylimidazole Concentration on Fe-ZIF-8 Catalyst for Oxygen Reduction in Acidic Medium

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Abstract

Noble-free Fe-N-C catalysts have emerged as promising materials for oxygen reduction reaction (ORR) in acidic medium, with potential applications in proton exchange membrane fuel cells (PEMFCs). Zeolitic imidazolate framework (ZIF-8) is a promising precursor for producing self-templated, highly ordered porous Fe-N-C with high structural stability upon pyrolysis. The ORR performance is influenced by particle morphology, pore distribution, and active sites, which are affected by the precursor composition and synthesis conditions. This study investigates the impact of varying the 2-methylimidazole (2mlm) precursor composition in the synthesis of Fe-ZIF-8-based catalysts on ORR activity. The 2mlm mole ratio in the precursors of Fe:Zn:2mlm:MeOH was varied to produce Fe-ZIF-8 via reflux method, which was then pyrolyzed to produce Fe-N-C catalysts. Electrochemical measurements were conducted in 0.1M HClO₄ using cyclic voltammetry and rotating-ring disc voltammetry techniques. Results revealed that low 2mlm composition produced the highest current density (4.30 mA/cm²) with clear limiting plateau. Further analysis of morphology and chemical structure will be conducted to correlate with electrochemical results. This work highlights the need for further optimization of Fe-ZIF-8-based catalyst synthesis to improve ORR activity and stability.

Keywords: Fe-ZIF-8; oxygen reduction activity; PEMFC.

Heat Treatment Effect on Nafion Incorporate with Hydroxyapatite for Direct Methanol Fuel Cell Application

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Abstract

Lignosulfonate- hydroxyapatite nanofillers (LS-HAP) were added to Nafion recast membranes to suppress methanol crossover and improve cell performance. A passive air-breathing single-cell direct methanol fuel cell (DMFC) was used to evaluate the performance of a membrane electrode assembly (MEA) with a composite membrane. This article deals with the synthesis of HAP from eggshells and the influence of annealing temperature on the synthesised composite membrane. The methanol crossover in the DMFC was determined using the cyclic voltammetry technique (CV). When comparing rN- LS /HAP 160x composite membranes with commercial Nafion 117 (175m) and composite membranes without annealing temperature, the rN- LS /HAP 160x composite membrane showed superior performance and reduced methanol permeability with maximum power density was achieved with 2 M methanol, outperforming the much thicker N117 under exact operating conditions. The results of the experiments showed that the use of LS-HAP as inorganic fillers for the Nafion polymer matrix has the potential to effectively minimise methanol crossover and increase performance in DMFC applications.

Keywords: composite membrane; annealing temperature; lignosulfonate-hydroxyapatite

Analysis of How Operating Parameters Impact Proton Exchange Membrane Fuel Cell PEMFC Stack Performance

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Abstract

Fuel cell technology has gained significant attention in recent years due to its potential to provide a clean and efficient source of energy. Fuel cells generate electricity through electrochemical reactions, using hydrogen or other fuels and producing water and heat as the only byproducts. Fuel cell stacks, which consist of multiple fuel cells connected in series or parallel, are a key component of fuel cell systems. The purpose of this analysis is to investigate the design, performance, and optimization of fuel cell stacks, with a focus on the proton exchange membrane fuel cell (PEMFC) stack. PEMFCs are widely used due to their high-power density, low operating temperature, and fast start-up time. In this experiment, the anode side is directly supplied with hydrogen, and an additional water flow is used instead of employing a humidifier after the hydrogen tank, which is the conventional approach. The water flow occurs between the bipolar plate and into the anode side. The power load is kept at 50 Ampere, the H₂ flow rate at 3 L/min, the air blower rate at approximately 100 L/min, and the water flow rate at 1.5 L/min. As a result, the highest power of 118.77W was achieved.

Keywords: PEMFC Stack; clean energy; stack performance

Lightweight PEMFC Bipolar Plate to Address the Costly Fuel Cell Issue: An Overview on Material Selection

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Abstract

With rising energy demand and diminishing resources, it is essential to explore and discover alternate energy sources to ease these issues. The proton exchange membrane fuel cell (PEMFC) is an electrochemical device that generates energy through an electrochemical process that does not involve combustion. As one of the newest and most prominent clean energy sources, PEMFC can not only meet the high-power requirements of new energy electric cars, but it is also suited for low power equipment like electronics. Notably, bipolar plate (BPs) is an essential multifunctional component in PEMFC that can evenly disperse the active gas in the active zone, collect the electrons generated by electrochemical reaction, and remove heat and exhaust gas. BPs account for approximately 80% of the weight and 45% of the cost of the fuel cell stack. Therefore, the production of low-cost, high-performance BPs is a prerequisite for large-scale application of PEMFC. Consequently, this study discussed thoroughly on materials, such as common base material used, surface treatment and coating of metallic BPs material, that commonly used for metallic BPs. This paper also reviewing the possible testing and characterization of PEMFC technology as to show how worth of these studies to be explore in detail.

Keywords: PEMFC, bipolar plate, lightweight, material, surface treatment, coating, testing, characterization

Hydrogen Production via Electrolysis Unit: Mathematical Modelling and Simulation on Parametric Towards PEM Electrolysis Performance

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Abstract

Commercial electrolysis, such as PEM electrolysis, has been widely used for hydrogen production. Previous studies have shown that PEM electrolysis requires no additional purification system and is even capable of producing hydrogen with a purity level of 99.9%. Additionally, significant progress has been made in improving the performance of PEM electrolysis, which can reduce capital investment costs. Therefore, this study focuses on the development of mathematical and simulation models for electrolysis units. The mathematical model is based on the mass transport of the components involved, as well as the electrochemical reactions occurring in the electrolysis unit. This model is then simulated using MATLAB R2015a software through the Simulink toolbar. The operating effects of the electrolysis unit, such as electrolyte flow rate, temperature, and pressure, as well as electrode characterization, such as the tortuosity and porosity, will be evaluated and analysed. Based on the simulation results, the effects of operating conditions and electrode characterization on electrolysis performance are determined through the polarization curve. The increased flow rate of electrolyte does not significantly affect the overall electrolysis performance. However, an increase in operating temperature can reduce energy consumption and resistance, leading to an increase in electrolysis cell performance. Therefore, the electrolysis performance increases with increasing operating temperature. Hence, the development of this electrolysis model can determine the optimal conditions without the need for laboratory experiments, saving costs.

Keywords: *Hydrogen production, clean energy, PEM electrolysis, mathematical model, simulation*

Unleashing the Fuel Cell Potential Through the Innovation in Cathode Catalyst Development

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Abstract

Fuel cells have emerged as a game-changing technology with the potential to revolutionize clean and efficient power generation. However, the performance and durability of catalyst materials in fuel cells remain a major challenge. In this study, we present a groundbreaking solution by introducing MXene as a catalyst support for Fe-N-C in fuel cell applications. MXene, a two-dimensional transition metal carbide or nitride, exhibits exceptional properties such as high surface area, electrical conductivity, and tunable surface chemistry. These characteristics make MXene a promising candidate for supporting catalytic nanoparticles in fuel cell electrodes. Our innovative approach of incorporating Fe-N-C onto $\text{Ti}_3\text{C}_2\text{T}_x$ MXene through a two-pot pyrolysis method demonstrated enhanced electrocatalytic activity, long-term stability, and resistance to degradation with more than 90% current stability and an impressive 80.8% increase in power density. This breakthrough has the potential to accelerate the adoption of hydrogen fuel cells as a clean and efficient power source.

Keywords: *MXene; catalyst support; stable; hydrogen fuel cell*

Effect of Post-Synthetic Modification of UiO-66-NH₂ in Polybenzimidazole Membrane towards Electrolyte Retention and Thermal Stability

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Abstract

High-temperature proton exchange membrane fuel cells (HT-PEMFCs) have a major advantage over low-temperature fuel cells (LT-PEMFCs) due to their tolerance to higher CO content in the hydrogen feed, simpler fuel processing, and better heat management. However, a key challenge in the development of HT-PEMFCs is the potential for acid leaching from phosphoric acid-doped polybenzimidazole (PBI) membranes, which can reduce overall performance. This study investigates the effect of post-synthetic modification (PSM) of the UiO-66-NH₂ metal-organic framework (MOF) on the acid electrolyte retention of MOF/PBI nanocomposite membranes. The MOF will be modified to create extra functional groups for proton transport, which is expected to increase the acid uptake and retention of the PBI membrane. Fourier transform infrared (FTIR) and ¹H nuclear magnetic resonance (NMR) spectroscopy will be used to study the chemical properties of the membranes and correlate them with the acid electrolyte uptake and retention of the nanocomposite membranes. Thermogravimetric analysis will be used to study acid electrolyte leaching and membrane decomposition properties. Further studies will focus on fuel cell performance analysis using the PSM MOF/PBI membrane to evaluate the feasibility of using PSM MOF as an additive to PBI for performance improvement.

Keywords: post synthetically modified (PSM); PBI; nanocomposite membrane.

Recent Application of Core-Shell Nanostructured Catalysts for CO₂ Thermocatalytic Conversion Processes

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Abstract

Carbon-intensive industries must deem carbon capture, utilization, and storage initiatives to mitigate rising CO₂ concentration by 2050. A 45% national reduction in CO₂ emissions has been projected by government to realize net zero carbon in 2030. CO₂ utilization is the prominent solution to curb not only CO₂ but other greenhouse gases, such as methane, on a large scale. For decades, thermocatalytic CO₂ conversions into clean fuels and specialty chemicals through catalytic CO₂ hydrogenation and CO₂ reforming using green hydrogen and pure methane sources have been under scrutiny. However, these processes are still immature for industrial applications because of their thermodynamic and kinetic limitations caused by rapid catalyst deactivation due to fouling, sintering, and poisoning under harsh conditions. Therefore, a key research focus on thermocatalytic CO₂ conversion is to develop high-performance and selective catalysts even at low temperatures while suppressing side reactions. Conventional catalysts suffer from a lack of precise structural control, which is detrimental toward selectivity, activity, and stability. Core-shell is a recently emerged nanomaterial that offers confinement effect to preserve multiple functionalities from sintering in CO₂ conversions. Substantial progress has been achieved to implement core-shell in direct or indirect thermocatalytic CO₂ reactions, such as methanation, methanol synthesis, Fischer–Tropsch synthesis, and dry reforming methane. However, cost-effective, and simple synthesis methods and feasible mechanisms on core-shell catalysts remain to be developed. This review provides insights into recent works on core-shell catalysts for thermocatalytic CO₂ conversion into syngas and fuels.

Keywords: *CO₂ hydrogenation; thermocatalytic reactions; sintering; coke formation; methanol synthesis*

Calcium Carbonate from Chicken Eggshells as Filler in Composite Nafion Membrane for Direct Ethanol Fuel Cell: A Molecular Dynamics Study

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Abstract

Direct ethanol fuel cells (DEFC) need fillers to mitigate the issue of ethanol crossing over from the anode to the cathode, which lowers performance. Therefore, this study developed calcium carbonate (CaCO_3) from chicken eggshells as a filler in a Nafion composite membrane for DEFC. Three cluster models of CaCO_3 filler were developed, namely $(\text{CaCO}_3)_2$, $(\text{CaCO}_3)_3$, and $(\text{CaCO}_3)_4$, to form the Nafion composite membranes. The properties of the composite membranes, such as proton conductivity, ethanol permeability, and selectivity, were studied using the molecular dynamics method. In addition, the three main factors influencing the composite membranes' properties were analysed in this study; these were the cluster size of CaCO_3 , mass loading of the filler, and ethanol concentration. The results show that the filler has reduced proton conductivity and ethanol permeability in DEFC applications compared to the Nafion membrane. However, selectivity is used as a trade-off between ion conductivity and ethanol permeability in the composite membrane, thus requiring a suitable size structure and mass loading to balance high ion conductivity rate and reduce ethanol permeability rate. The composite membrane C- $(\text{CaCO}_3)_4$, which has a large cluster size in this study, shows that it is necessary to restrict ethanol permeability at a high ethanol concentration of 5 mol L^{-1} . However, the structure size in cluster B – $(\text{CaCO}_3)_3$ – can reduce ethanol permeability but requires high mass loading by 5 wt.%. Analysis of variance showed significant values for ion conductivity, ethanol permeability, and selectivity responses. CaCO_3 successfully reduced ethanol crossover in DEFC, with all three composite membranes being suitable for use at low ethanol concentrations. However, specific size structure and mass loading are required to overcome ethanol crossover at high ethanol concentration.

Keywords: *transport properties; molecular dynamics; fuel cell*

Synthesis and Characterization of Biomass-Derived Graphene Oxide and Titanium Dioxide TiO₂ as Potential Materials for Development of Microporous Layer (MPL) in Direct Methanol Fuel Cells

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Abstract

Direct methanol fuel cells (DMFC) are green energy devices which are commonly used for portable applications, due to their simple setup and easy fuel handling. Managing methanol fuel crossover in this type of fuel cell is vital to maintain optimal performance, which can be accomplished by using microporous layers (MPL) as part of the membrane electrode assembly (MEA), the core of the fuel cell. In this work, two materials which are gaining attention in fuel cell development, namely graphene oxide and titanium dioxide TiO₂ were synthesized. Graphene oxide was synthesized via modified Hummer's Method using pyrolyzed palm oil biomass as the raw material, while TiO₂ was synthesized via Sol-Gel Method. Their physicochemical characteristics were then analysed via Field Emission Scanning Electron Microscopy (FESEM), Brunauer Emmett Teller (BET), Raman spectroscopy, and X-ray Diffraction (XRD) to determine their capabilities to be utilised for development of MPLs in DMFCs. Comparing with commercially available materials, the characteristics of the synthesized TiO₂ and biomass-based graphene oxide in this work displayed similar quality. Thus, these findings provide promising results for the two materials to be used for fabrication of MPLs as part of DMFCs.

Keywords: Graphene oxide; Titanium dioxide; methanol fuel cell

Performance Analysis of 2kW Hydrogen Fuel Cell used in Lightweight Vehicle

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Abstract

Fuel cell vehicles (FCVs) offer a promising alternative to traditional gasoline and electric vehicles, boasting advantages such as zero emissions, long range, and quick refuelling times. A FCV is an electric vehicle that utilizes a fuel cell, sometimes in combination with a supercapacitor, to power its onboard electric motor. The focus of this paper is to present the experimental results from a study investigating the dynamic performance of a fuel cell vehicle. This paper focuses on the experimental findings from a study investigating the dynamic performance of a fuel cell vehicle with an 800W-powered motor and a 2kW proton exchange membrane fuel cell (PEMFC) stack. The study involves two categories of experimental road testing: one using only the fuel cell and the other employing both the fuel cell and a supercapacitor. The primary objective is to observe the fuel cell's behaviour regarding power output, current, and voltage under different road conditions and loads. The experimental results from laboratory and road tests reveal the timely dynamic responses of the fuel cell stack's current and voltage to load variations. Notably, during quick high-load applications on the fuel cell, instances of current overshoot and voltage undershoot are observed. These phenomena are closely associated with the charge double-layer effect and mass transfer mechanisms involving the fuel cell's water and gas transport and distribution. The fuel cell stack demonstrates a high-power output, while the supercapacitor offers quick bursts of power when needed. The fuel cell vehicle with a supercapacitor exhibits excellent transient response, especially during climb tests, enabling smooth acceleration and deceleration. The findings emphasize the importance of incorporating a supercapacitor as a power boost system for fuel cell vehicles, as it enhances their dynamic performance and effectively meets vehicular power demands. Overall, this research underscores the potential for fuel cell vehicles with a supercapacitor to deliver excellent dynamic performance, presenting a viable solution for sustainable transportation.

Keywords: Proton Exchange Membrane Fuel Cell; Fuel Cell Vehicle; dynamic performance

Nanotextured Cobalt in Bifunctional Oxygen Electrocatalyst for Renewable Energy Systems: Current Developments and Outlook

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Abstract

Cobalt-based nanomaterial is a promising electrocatalyst material for various types of renewable energy systems relating to their excellent merits of highly active catalytic properties, good thermal/chemical stability as well as high theoretical capacity. On the other hand, when embedded with property-complementary nanomaterials, such as carbon, graphene, CNTs, heteroatom, metal oxides/sulfides and polymers, their electrocatalytic performance can be further enhanced in terms of reversibility of oxygen electrodes, cycling stability, rate capability and catalytic activity. In current review, the advancement of cobalt-based nanomaterials from zero- to three-dimensional in their discrete and composite nanotopography modifications on the cathode electrode to exhibit outstanding oxygen bi-functional electrocatalytic performance. Accurate attention was applied to synthesize method, doping and topography effect, and electrochemical performance on recent research conducted mainly on investigations with ORR and OER actions in metal-air-batteries and fuel cells. The gaps encountered in the knowledge of recent research for better performance are well presented.

Keywords: cobalt; multidimensional; single atom; oxygen bifunctional; fuel cell

A Short Review on Biomass-Derived Carbon Quantum Dots Photocatalyst for Solar Cells Application

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Abstract

Carbon quantum dots (CQDs) are a novel class of carbon nanomaterials with fluorescence consisting of discrete, quasi-spherical carbon nanoparticles. Recently, the electronic and optical properties of CQDs have gained interest over semiconductor quantum dots (SQDs). The use of renewable and inexpensive biomass resources to prepare the CQDs may promote the development of sustainable applications and meet the urgent need for large-scale synthesis biomass. Solar cell application is preferred, as CQDs have the capability to harvest longer wavelengths of solar energy and make it an outstanding photocatalyst for solar cell application due to its ability for down- and up-conversion of Photoluminescence (PL). In addition, different types of functionalization routes and precursors give rise to different functional groups on the surfaces of CQDs and improve its performance in photocatalytic activities. This review is an attempt to provide a recent summary on biomass-derived carbon quantum dots photocatalyst for solar cells application involving the aspects of CQDs synthesis methods, photocatalytic activities as well as future opportunities on the studies.

Keywords: *biomass; photocatalyst solar cell; carbon quantum dots*

Effect of Cu Phase Confinement in Porous Alumina on the Structure-Activity Relationship in Catalytic CO₂ Hydrogenation

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Abstract

Unlike nanostructured metal-supported catalysts, core-shell structured catalysts (CSSC) contained an encapsulated metallic core by metal oxide shell materials, hinting at much more pronounced metal-support synergistic effect. Herein, we study a series of Cu@Al₂O₃ core-shell nanostructured catalysts with different Cu core loading to quantitatively investigate the stability and activity of encapsulated Cu phases within the inner porous channel of alumina shell and how the Cu-Al₂O₃ interaction will influence the catalytic performance of carbon dioxide hydrogenation at low, mild and high temperature of CO₂ hydrogenation reaction. A series of Cu@Al₂O₃ catalysts were synthesized using a wet chemical double-step method with different Cu loading to probe the promoting role of the copper phase for methanol yield and CO₂ conversion enhancement. Physicochemical properties of the catalysts were characterized via FESEM, XRD, TEM, BET, CO₂-TPD, H₂-TPR and N₂O-sorption to assess the nature of synthesized Cu-based core-shell catalysts and its interaction with shell materials for enhanced CO₂ chemisorption. The octahedron shape of Cu@Al₂O₃ catalysts has formed with the presence of several Cu⁰/Cu⁺ active phases within the interface layer of core-shell attributed to more conversion of CO₂ to CO and methanol products compared to conventional supported catalyst.

Keywords: core-shell, methanol synthesis, decarbonisation, catalysts

Exploring Molybdenum Carbide as Electrocatalysts for Oxygen Reduction Reactions (ORR)

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Abstract

The catalytic activity of platinum (Pt) in hydrogen oxidation (HOR) and oxygen reduction (ORR) reactions has been extensively studied and recognized for its effectiveness. However, the high cost associated with Pt usage, coupled with its susceptibility to react with substances like carbon monoxide (CO), especially when low-purity H₂ and O₂ are used, leads to catalyst poisoning and compromising catalysis stability. To address these challenges and reduced Pt dependency in Proton Exchange Membrane Fuel Cells (PEMFC), researchers have explored alternatives such as the two-dimensional material of Mxene. Among various Mxene, molybdenum carbide (Mo₂C) has shown promising properties such as high hardness, good thermal and chemical stability. In this study, we assess the electrocatalytic performance of Mo₂C for both HOR and ORR using Density Functional Theory (DFT) calculation that was performed using CASTEP software. A Bader charge analysis indicates that the exposed Mo atoms bonded to OOH groups play a pivotal role in electron transfer from the catalysts to the OOH groups, leading to the high catalytic activity of ORR compared to HOR. Therefore, it is suggested that materials with exposed transition-metal atoms may serve as excellent electrocatalysts.

Keywords: *density functional theory; oxygen reduction reaction, hydrogen evolution; MXene; PEMFC*

Exploring the Influence of Sintering Temperature on the Characteristics of Ni-BCZY Composite Anode for Application of Protonic Ceramic Fuel Cells

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Abstract

Investigating the impact of sintering temperature on Ni-BaCe_{0.54}Zr_{0.36}Y_{0.1}O_{3-δ} (Ni-BCZY) composite anode is crucial for protonic ceramic fuel cell (PCFC) application. NiO-BCZY composite powder with 50wt%:50wt% is prepared by the sol-gel method. The optimal calcination temperature of 1100 °C is determined by thermogravimetric analysis. While XRD analysis shows a single cubic phase with lattice parameter, a of 4.332 Å. FESEM confirms the homogeneity of the powder with an average particle size of 51 ± 16 nm. BET technique measures the specific surface area as 6.25 m²/g. Sintering temperature (1200–1400 °C affects the anode properties. The thickness of the anode film decreased from 28.95 µm to 26.18 µm and porosity decreased from 33.98 % to 26.93 % with increasing temperature. Electrical conductivities at 800 °C are 443 S/cm, 633 S/cm and 1124 S/cm for anode sintered at 1200 °C, 1300 °C and 1400 °C respectively. Anode sintered at 1400 °C exhibits the lowest area specific resistance (ASR) of 1.165 Ωcm² under humidified (3% H₂O) gas mixture of H₂ (10%) and N₂ (90%) at 800 °C.

Keywords: Ni-BCZY anode; protonic ceramic fuel cell; sintering temperature

Effect of Hydrothermal Reaction Temperature on Surface Morphology and Structural Properties of Zinc Oxide on Graphene/Nickel foam for Photoelectrochemical Water Splitting

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Abstract

Photoelectrochemical (PEC) water splitting is a promising technique for producing hydrogen (H₂) as a future clean energy source. Many efforts have been made to improve PEC efficiency by utilizing semiconductor materials. However, the performance of PEC is constrained by the wide band gap and high recombination rate of electron-hole pairs. Our findings indicate that the structure of ZnO can be controlled by adjusting the hydrothermal reaction temperature and incorporating Graphene/Nickel foam (Ni-foam) as a co-catalyst, which significantly enhances light absorption and PEC performance. Field emission scanning electron microscopy (FESEM) and energy-dispersive X-ray (EDX) mapping analysis reveal the morphological structure of ZnO on Graphene/Ni-foam. High-resolution transmission electron microscopy (HR-TEM), Raman, and X-ray diffraction (XRD) analysis confirm the successfully growth of Graphene/Ni-foam and ZnO on Graphene/Ni-foam. Furthermore, photocurrent measurement and electrochemical impedance spectroscopy (EIS) analysis suggest that ZnO on Graphene/Ni-foam demonstrates outstanding efficiency in separating photogenerated electron-hole pairs due to the flower- and hexagonal-rod-like structure of ZnO and the porous nature of the substrate. This promotes the presence of more photocatalytic active sites for the reaction. ZnO on Graphene/Ni-foam, synthesized via chemical vapor deposition (CVD) and hydrothermal methods, exhibits an excellent photocurrent density of 73.04 at ~1.0 V versus Ag/AgCl in 0.5 M Na₂SO₃. This work describes an intriguing strategy for developing sustainable photoanodes for PEC water splitting.

Keywords: zinc oxide; graphene; photoanode; hydrogen production; photoelectrochemical water splitting

Decal Method for Catalyst-Coated Membrane Electrode Assemblies in Laboratory-Scale PEM Electrolyzers

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Abstract

Proton Exchange Membrane Electrolyzers (PEM electrolyzers) have emerged as a promising technology for clean and renewable hydrogen gas production through water electrolysis. Among the various methods used for catalyst coating, the Catalyst Coated Membrane (CCM) approach stands out as a simpler and more efficient alternative to the indirect coating method. However, direct catalyst deposition onto the membrane faces challenges related to the transfer rate of the catalysts during the coating process. This study focuses on controlling the catalyst transfer rate in the direct catalyst coating method, aiming to fabricate high-quality Membrane Electrode Assemblies (MEAs) for a laboratory-scale PEM water electrolyzer (PEMWE). The decal method was employed to optimize a Catalyst-Coated Membrane Electrode Assembly (CCM-MEA) and investigate other factors that could impact the efficiency and durability of the MEAs. The CCM-MEA was manufactured using Nafion 117 and Nafion 212 membranes of different sizes (5 cm², 25 cm², and 36 cm²) with an IrO₂ coating on the anode side and Pt/c on the cathode side. Various transfer substrates, including PTFE, KEPTON, and Teflon cloth, were tested for their catalyst transfer efficiency. A thin ionomer layer was added on top of the catalysts to facilitate the transfer, and the sample was sandwiched between folded aluminum foil before the hot press stage. The hot press was conducted at 130 °C, 700 psi, and 5 minutes, followed by cold peeling for 3 minutes. The CCM-MEA's performance was evaluated regarding current density under different operating temperatures (room temperature, 30 °C, and 60 °C). The findings indicate that the 36 cm² Nafion 117 membrane operating at 2.0 voltage exhibited the best performance among all membrane sizes tested. Additionally, the Teflon cloth demonstrated a remarkable catalyst transfer rate of over 95% compared to other transfer substrates. This study provides valuable insights into the optimal design of CCM-MEAs and offers a comprehensive understanding of their long-term performance and durability in PEM water electrolyzers. The results contribute to advancing the state-of-the-art in PEM electrolysis technology, fostering the realization of efficient and sustainable hydrogen production systems.

Keywords: CCM MEA; decal method; PEM electrolyzer

Comparative Analysis of Bipolar Plate Characteristics in PEMFC and PEMWE

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Abstract

Proton exchange membrane fuel cell (PEMFC) as power generator and proton exchange membrane water electrolyser (PEMWE) as hydrogen fuel producer play critical roles in the implementation of hydrogen energy. The bipolar plates in both PEMFC and PEMWE facilitates reactant and product flow, providing electrical connectivity in a series of singular cells. Although both systems are categorised under the same proton exchange membrane (PEM) spectrum, the differing mechanisms require specialised plate properties to achieve optimum performance. This short review analyses the characteristics of bipolar plates in both PEMFC and PEMWE, with focus on the flow field, plate structure and material. The discussion is constructed with several tabulated data which highlighted significant findings and research trends in the past decade. The findings conclude that serpentine flow field is the best design to promote higher electrochemical output in PEMFC through uniform reactant distribution and efficient liquid water drainage. PEMFC bipolar plates are commonly rectangle, with graphite as the main material due to its durability, and lower cost. On the other hand, PEMWEs commonly adopt the parallel flow field for its lower contact impedance and efficient mass transfer. The plate is constructed in a circular shaped and is metallic based to drastically reduce corrosion from oxygen evolution reaction. This work provides comprehensive information that may be helpful in the construction of PEMFC and PEMWE systems.

Keywords: *flow field; bipolar plate; fuel cell; electrolyser*

Harnessing Microbial Electrochemical Systems for Eco-Friendly Wastewater Treatment and Energy Conversion

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Abstract

Amidst global concerns about wastewater, clean water availability, and energy resources, factors like population growth, technological advancements, and rapid industrialisation have intensified these challenges. Notably, sewage production has surged with urbanisation, posing environmental risks and jeopardising human health due to water's vital role. Addressing this issue requires energy-efficient, eco-friendly wastewater treatment methods to curtail the harmful impact on the environment and save energy, often sourced from fossil fuels and hydroelectricity, causing further ecological harm. One promising approach is utilising microbial electrochemical system (MES) technology, known for its sustainable attributes. Unlike conventional batteries, MESs integrates biotic elements, hosting live bacteria engaged in life processes. They employ non-hazardous organic matter-based electrolytes, enabling bacterial growth and energy conversion via biochemical reactions. This contrasts with traditional batteries reliant on metal ion redox reactions. Microorganisms like *Geobacter sulfurreducens* play a catalytic role, transforming high-energy organic waste into electricity. This method generates energy and effectively treats organic waste, such as palm oil mill effluent, mitigating environmental pollution. Generally structured with an anaerobic anode chamber containing bacteria and an aerobic cathode chamber, MESs employs a membrane to separate the two. Oxidation reactions within bacteria yield electrons, which can be harnessed while maintaining an adequate food source. Although MESs hold promises, challenges persist, especially in optimising electron transfer efficiency. Pioneered by the Fuel Cell Institute of Universiti Kebangsaan Malaysia under the Biofuel Cell Group, MES research seeks to overcome these obstacles and realise the synergy of waste treatment and energy generation. In conclusion, MES is a promising avenue that offers effective waste management and sustainable energy generation. Continued research and technological enhancements are crucial to unlocking their full potential.

Keywords: *microbial electrochemical system; biofuel cell group; fuel cell institute*

Photoelectrochemical Technology for Solar Fuels: Green Hydrogen, Carbon Dioxide Capture and Ammonia Production

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Abstract

The growing demand for sustainable energy sources has led to increased interest in exploring novel technologies that can use solar energy to produce fuel and address environmental concerns. Solar energy conversion into fuels and chemicals that can be stored and transported has become an important topic of research in renewable energy. Photoelectrochemical (PEC) technology is a promising strategy that can directly convert sunlight into chemical energy. By harnessing sunlight PEC technology can convert water, carbon dioxide, and nitrogen into useful fuels. At the heart of this technology is the semiconductor photoelectrode that absorbs light and generates charge carriers due to the photoelectric effect which drives conversion of light energy into solar fuels at the photoelectrode interface. Direct solar water splitting through PEC process is a very attractive method for green hydrogen (H₂) production with input of only sunlight and water. The PEC technology also has potential to capture carbon dioxide (CO₂) and convert it into fuels such as methanol using sunlight and water. Besides this, PEC technology also has the capability to convert nitrogen (N₂) and water (H₂O) to produce ammonia (NH₃) which acts as transportable hydrogen storage. The reversed process, which is the cracking of NH₃ to produce H₂, can also be accomplished using PEC technology. Advancement in material development has significantly improved PEC performance. However, stability, efficiency, and scalability issues need to be resolved for practical application of these systems. Even so, PEC technology has a lot of potential as a clean and sustainable solution for addressing global energy and environmental challenges.

Keywords: *photoelectrochemical; solar fuels; sustainable energy*

Effect of Al^{3+} dan Fe^{3+} Substitutional Doping in Ni-rich $\text{LiNi}_{0.8}\text{Co}_{0.2}\text{O}_2$ Cathode Material for Li-ion Battery: Preparation, Characterization and Electrochemical Properties

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Abstract

Nowadays, nickel-rich layered oxide cathode material was one of the most researched cathode materials in the battery world as it has the potential to replace the long-standing commercial lithium cobalt oxide, LiCoO_2 (LCO). Despite cobalt playing an important role in the structural stability of cathode material, the need to reduce the cobalt content was mainly due to the scarcity of cobalt resources, high price fluctuations, and child labour issues that cannot be ignored. As nickel is abundant and cost-effective, it gives the advantage for Ni-rich cathode material to be more outstanding than other types of material. However, it has severe drawbacks such as difficulty to synthesize and higher cation mixing resulting in poor electrochemical performance. In this research, the synthesis of $\text{LiNi}_{0.7}\text{Co}_{0.3}\text{O}_2$ (LNC) cathode material was done using the combustion method where citric acid act as fuel. To improve the structural stability of LNC, 1% Fe was substitutional doped at the cobalt site in the LNC material. The material was then characterized by using X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscopy (FESEM) and Energy Dispersive X-Ray Spectroscopy (EDX). XRD analysis shows that all materials were pure, single phase and isostructural with $R\bar{3}m$ space group. All synthesized samples also show a pattern of an irregular polyhedral shape with a close stoichiometry of elemental composition to theoretical stoichiometry. In comparison to pristine LNC material, Fe-doped LNC material is found to have lower cation mixing and a higher c-axis value indicates the better structural stability in the material. Moreover, Fe-doped material has the highest discharge capacity of 135 mAhg^{-1} and improved the capacity fading by more than 5 % over the 50th cycle. All this evidence proves that the substitution of Fe^{3+} in LNC material help in improves the stability of the crystal structure and retain their electrochemical properties.

Keywords: Ni-rich; combustion; Fe-doped

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