

Topical Symposium on Sustainable Surface Engineering Room Town & Country B - Session TS1-1-MoM

Coatings for Batteries and Hydrogen Applications I

Moderators: Martin Welters, KCS Europe GmbH, Germany, Chen-Hao Wang, National Taiwan University of Science and Technology, Taiwan

10:00am **TS1-1-MoM-1 Coating Innovations for Green Energy: Enabling Hydrogen Technologies**, Mehmet Öte [oetehm@schaeffler.com], Schaeffler Technologies AG & Co. KG, Germany **INVITED**

In light of urgent climate challenges, the transition from fossil fuels to green energy sources necessitates significant advancements in hydrogen technologies. This keynote presentation will emphasize the crucial role of innovative coatings across all components of electrolyzers and fuel cells, including bipolar plate coatings, transport layer coatings, and catalyst-coated membranes. We will provide a comprehensive review of the evolving requirements for these coatings, assessing their impact on both performance and sustainability.

Key focus areas will include advancements in anti-corrosion and electrically conductive coatings designed to enhance the efficiency and lifespan of components within hydrogen systems. These innovations not only achieve exceptional electrical conductivity and corrosion resistance but also play a pivotal role in significantly reducing the CO₂ footprint of critical components. Ultimately, this talk aims to contribute to the ongoing discourse in the energy sector, demonstrating how advanced materials and coatings can facilitate the widespread adoption of hydrogen as a clean energy carrier.

10:40am **TS1-1-MoM-3 Intermediate-Temperature Proton-Conducting Solid Oxide Fuel Cells and Electrolyzers for Clean Energy**, Sheng-Wei Lee [swlee@ncu.edu.tw], Chung-Jen Tseng, Szu-Yuan Chen, National Central University, Taiwan **INVITED**

The solid oxide cells (SOCs), which can operate in fuel cell or electrolyzer mode, is a promising technology to store electrical energy as chemical energy and to reconvert it into electricity upon demand. In recent years, extensive efforts have been devoted to developing proton-conducting SOCs (P-SOCs) that operate in the low-to-intermediate temperature range (400-800 °C). Compared to the conventional oxygen ion-conducting SOCs (O-SOCs) that require high operating temperature (800- 1000 °C), this scheme enables more reliable sealing, use of cheaper materials for interconnect, and a better control of electrode/electrolyte interactions, thus prolonging the operational lifetime of SOCs.

In this presentation, a variety of nanostructured electrode for P-SOCs is demonstrated via nano-engineering and have demonstrated their excellent cell performance. For example, we present a nanofiber-derived functional anode and cathode for proton-conducting SOFCs. The significantly lower polarization resistance elements indicate that the nano-fibrous electrode has superior catalytic activity for HOR and ORR. We also use PS nanospheres as pore former to fabricate an LSCF cathode with graded porosity, thus greatly improving the cell performance. In addition, we employ spin-coating technique and pulsed laser deposition (PLD) with doping strategy to fabricate thin-film electrolyte for P-SOCs. A bulk heterojunction GCCO-BCZY layer with a domain width of ~5 nm by PLD via spontaneous phase separation is demonstrated as an electrolyte/cathode interlayer, which effectively increases the interfacial area between the two distinct phases and facilitates proton transport across the interface. Finally, we also discuss the SOC performance when fed with a variety of fuels and in the electrolysis mode.

11:20am **TS1-1-MoM-5 Development of Anode Electrodes for Water Electrolysis by Electroplating**, Pei-Chi Lin, Chieh-Fu Huang, Yong-Song Chen [imeysc@ccu.edu.tw], National Chung Cheng University, Taiwan **INVITED**

Anion exchange membrane water electrolysis (AEMWE) has drawn much attention recently as a sustainable and cost-effective method for hydrogen production. Unlike proton exchange membrane water electrolysis, AEMWE employs non-precious metal as catalysts, which can significantly reduce material costs. However, it remains challenging to develop efficient and durable anode electrodes that can withstand alkaline environments while maintaining high performance in the oxygen evolution reaction (OER). In this study, stainless steel paper (SSP) is employed as the porous transport layer (PTL) of the anode in AEMWE. The effects of various surface modifications on SSP are investigated to assess their impact on

electrochemical performance, including heat treatment, acid treatment, and electroplating.

Surface morphology, Brunauer–Emmett–Teller (BET) surface area, and current-voltage (I-V) characteristics are analyzed across treatments to evaluate their impact on catalytic activity. Results indicate that electroplating nickel (Ni) onto acid-treated SSP significantly enhances anode performance, achieving over a 10% increase in efficiency compared to untreated SSP. This enhancement is attributed to the increased specific surface area provided by acid treatment, combined with the catalytic benefits of Ni from electroplating. BET analysis supports that acid treatment creates a rough surface on the SSP fibers, thereby increasing active surface area. Additionally, I-V curves demonstrate that Ni-electroplated, acid-treated SSP exhibits lower overpotentials and higher current densities. This approach utilizes low-cost, commercially available stainless steel, supporting the potential for mass production and enhancing the economic feasibility of AEMWE in hydrogen production applications.

12:00pm **TS1-1-MoM-7 Development of Three-Dimensional Lithium Metal Composite Electrode with Lithiophilic ALD Coating**, Yu-Lun Cheng, Chih-Liang Wang [wangcl@mx.nthu.edu.tw], National Tsing Hua University, Taiwan

Lithium (Li) metal is widely regarded as an ideal anode material for lithium-ion batteries thanks to its high theoretical capacity (3860 mAh/g) and low electrochemical potential (-3.04 V vs. standard hydrogen electrode). However, practical use is limited by challenges such as lithium dendrite growth, volume expansion, and dead lithium, which degrade performance. This study addresses these issues by applying atomic layer deposition (ALD) of zinc oxide (ZnO) onto electrospun carbon nanofibers (CNFs) to create a high-performance, three-dimensional (3D) lithium metal composite anode. Polyacrylonitrile (PAN) was first electrospun to form the CNF framework. The lithiophilic properties of CNFs were systematically explored by adjusting the number of ALD ZnO cycles. The 3D lithium metal composite anodes were then produced by infusing molten lithium into the ZnO-coated CNFs. These composite electrodes showed excellent electrochemical performance, including low overpotential and extended cycle life in symmetric cell tests. In full-cell tests with LiFePO₄, the 3D Li composite anode delivered higher capacity than traditional Li metal foil. Overall, the combination of electrospinning and ALD techniques demonstrates substantial potential in creating 3D lithium metal composite electrodes, offering improved lithium diffusion, current distribution, battery stability, cycle life, and rate performance.

Topical Symposium on Sustainable Surface Engineering Room Town & Country B - Session TS1-2-MoA

Coatings for Batteries and Hydrogen Applications II

Moderators: Chen-Hao Wang, National Taiwan University of Science and Technology, Taiwan, Martin Welters, KCS Europe GmbH, Germany

1:40pm TS1-2-MoA-1 The Effect of the Transition Metal Dopant on the Microstructure and Electrochemical Performance of Magnetron Sputtered Electrodes for Solid Oxide Fuel Cells Applications, Justyna Kulczyk-Malecka [j.kulczyk-malecka@mmu.ac.uk], Katharina Steier, David Shaw, Kleitos Panagi, Peter Kelly, Manchester Metropolitan University, UK

The electrolytic energy conversion has become one of the main technologies considered to deliver actions on reducing CO₂ emissions in the energy, heavy-duty transportation and industrial processes sectors. The electrolytic cells (fuel cells and electrolysis cells) can be utilised in energy conversion, generation, and storage, which has been demonstrated at scale in many regions around the world already. Solid oxide cells are typically composed of porous ceramic matrix and Ni metal catalyst fuel electrodes, dense ceramic electrolytes, such as YSZ or GDC, and perovskite air electrodes. These cells operate at relatively high temperatures (typically 600-850°C) and, therefore do not require precious metal group catalysts to drive the reaction forward in both electrolysis (H₂ generation) and fuel cell (energy conversion) modes. Moreover, they are more versatile in terms of required fuel type allowing utilisation of hydrogen as well as alternative fuels, such as methanol, ammonia, or biogas.

In this work, thin (~3 µm) nanostructured cermet anodes consisting of YSZ-Ni and GDC-Ni were doped with transition metals to study their influence on coatings microstructure and electrochemical performance. The anodes were deposited onto commercial YSZ electrolyte support cells using oblique angle pulsed DC reactive magnetron sputtering. The coating microstructure was evaluated using FIB-SEM and TEM and focused on the triple-phase boundary evolution in relation to the amount of the added dopant (0-5 wt.%). The chemical composition of the coatings was assessed using EDX, XPS and XRD analysis. The polarization curves were obtained from SOFC single stack assemblies under hydrogen and air flows for anode and cathode, respectively, at operating temperatures of 850°C to evaluate the electrochemical performance of the deposited films.

2:00pm TS1-2-MoA-2 Investigation of Ba_{0.5}Ce_{0.3}Zr_{0.18}Yb_{0.01}O_{3-δ}/Y_{0.2}Ce_{0.8}O_{2-δ} Composite Coatings for the Electrolyte of Solid Oxide Fuel Cell, Yen-Yu Chen [yychen@mail.npust.edu.tw], Ke-Hsing Wang, National Pingtung University of Science and Technology, Taiwan

Solid oxide fuel cells (SOFCs) are one of the potential power generation devices for the sources of renewable energy. In this study, the composite coatings consisted of BaCe_{0.7}Zr_{0.12}Y_{0.1}Yb_{0.1}O_{3-δ} (BCZYYb) and Y_{0.2}Ce_{0.8}O_{2-δ} (YDC) were developed by a colloidal coating process as the electrolyte for SOFC. Both of the powders of BCZYYb and YDC were synthesized by the solid-state reaction methods. The well dispersed suspensions after refined by the planetary ball method were spin coated on the porous NiO/BaZr_{0.85}Y_{0.15}O_{3-δ} (BZY) substrates, which were prepared by a die pressing method after pre-sintering at 1200°C for 1 h. Several properties were analyzed including microstructures, crystallographic phases, and electrical performance. The BCZYYb/YDC composite coatings still showed dual-phases including perovskite-type BCZYYb and fluorite-type YDC after sintered at 1550°C for 24 h. The coating layer shows high density after sintered. And the thickness of the coating layers are around several µm. The composites show ionic conductive behaviors from the temperature between 500~800°C. The details will be reported in the presentation.

2:20pm TS1-2-MoA-3 Unveiling the ORR Mechanism on Co Single-Atom Catalysts Using Operando Raman Spectroscopy with Catalyst-Coated Membrane (CCM) Methodology, Sun-Tang Chang [suntang925@gmail.com], Yi-Qing Chu, Zih-Jhong Huang, Chen-Hao Wang, National Taiwan University of Science and Technology, Taiwan

In this study, operando Raman spectroscopy was employed to investigate the mechanism of the oxygen reduction reaction (ORR) on a cobalt single-atom catalyst (Co-SAC). The Co-SAC was synthesized and utilized as a cathode catalyst for an alkaline anion exchange membrane fuel cell (AAEMFC). The results demonstrate excellent ORR activity, with an electron transfer number of 3.96 and J_{lim} is 5.5 mAcm⁻².

X-ray absorption spectroscopy (XAS) revealed that the Co-SAC features a Co-N5 coordination structure, with cobalt in the +3 oxidation state.

Furthermore, wavelet transform (WT) analysis confirmed the presence of isolated cobalt single atoms.

To minimize interference from the electrolyte during Raman laser measurements, the catalyst-coated membrane (CCM) method was adopted. This approach effectively prevents direct interaction between the laser and the electrolyte while ensuring efficient OH⁻ group transfer to the catalyst. Additionally, in the operando setup, electrochemical impedance spectroscopy (EIS) was integrated with Raman spectroscopy. This combination enabled a detailed observation of the ORR mechanism and the evolution of surface phenomena under different applied biases.

This study represents a significant breakthrough in unveiling the ORR mechanism, particularly for Co-based single-atom catalysts.

2:40pm TS1-2-MoA-4 Study on Mo_xN Thin Films Deposited by HiPIMS and RF Sputtering with Heteroatom Doping for Hydrogen Evolution Reaction Catalysts, Hung-I Wu [a8794191@gmail.com], National Yunlin University of Science and Technology, Taiwan; Ying-Hsiang Lin, National United University, Taiwan; Shih-Hung Lin, National Yunlin University of Science and Technology, Taiwan; Fan-Bean Wu, Chi-Yueh Chang, National United University, Taiwan; Thi Xuyen Nguyen, Chia-Ying Su, Ruei-Chi Lin, Jyh-Ming Ting, National Cheng Kung University (NCKU), Taiwan; Wan-Yu Wu, National United University, Taiwan

In recent years, materials such as transition metal oxides and nitrides have been popular in catalyst research. Compared to scarce noble metals, molybdenum-based materials not only have more abundant resources but also exhibit excellent activity[1], making them highly suitable to replace the costly noble metal catalysts (Ru, Ir, RuO₂, IrO₂). Molybdenum nitride (MoN) possesses outstanding corrosion resistance and electronic conductivity[2], allowing it to perform the hydrogen evolution reaction (HER) in acidic media. If different elements like Ti, Co, Ni, and V are doped into Mo_xN as a substrate, a synergistic effect is expected to further enhance HER performance. Additionally, when attaching catalysts to electrodes, one must consider the uniformity of surface coverage and adhesion on electrodes of various shapes. As is well known, sputtering offers advantages such as uniform coating, easy control of film thickness, and excellent adhesion. Therefore, using this method to prepare catalyst thin films on electrodes is the optimal choice.

In this study, we employed RF sputtering and High Power Impulse Magnetron Sputtering (HiPIMS) techniques to deposit Mo_xN thin films for comparison. Initially, we deposited Mo_xN thin films using HiPIMS and found in preliminary results that the HiPIMS-deposited Mo_xN thin films exhibited an overpotential of 415 mV at η=10 during hydrogen evolution reaction (HER) tests in 0.5M H₂SO₄. Energy-dispersive X-ray spectroscopy (EDS) analysis revealed that the Mo and N contents in the Mo_xN thin films were 60 at.% and 40 at.%, respectively. Grazing-incidence X-ray diffraction (GIXRD) results indicated that the thin films have a face-centered cubic (FCC) structure similar to Mo₃N₂. Building on these Mo_xN results, we will further explore the impact of varying the N/Mo ratio on HER performance. Additionally, we plan to attempt doping other elements into Mo_xN to observe the changes induced by doping.

3:00pm TS1-2-MoA-5 Ternary FeCoNi / Graphene Composites as Electrocatalysts for Highly Efficient Hydrogen Evolution Reaction, Yu Tsung Lin [asd881228@gmail.com], Jow Lay Huang, Sheng Chang Wang, Yu Min Shen, National Cheng Kung University (NCKU), Taiwan

As a consequence of the depletion of fossil fuels, the escalating energy crisis has driven researchers to explore innovative energy. To address this problem, exploring hydrogen energy generation via water splitting emerges as a promising solution. This process involves the hydrogen evolution reaction (HER), a multi-electron transfer process necessitating catalysts to facilitate efficient rates. Despite noble metals have conventionally served this purpose due to their favorable Gibbs free energy, their prohibitive costs pose challenges for widespread adoption and commercialization. In response, our investigation focuses on HER within alkaline electrolytes, aiming to engineer alternative electrocatalysts that are both cost-effective and efficient.

Transition metals from the first row are active centers for the HER due to their 3d orbital, exhibiting excellent activity. Among them, nickel (Ni) and cobalt (Co) shows the most promising potential because the hydrogen adsorption energy of them approaches that of Pt. Furthermore, recent studies have indicated that the incorporation of third transition metals, such as iron (Fe), can further enhance the HER activity. This is attributed to the synergistic effect among the three metals. Additionally, it can be observed that a large number of studies use two-dimensional carbon materials as supports. Graphene, a highly conductive 2D material, serves as

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an excellent supporting matrix due to its high surface area, facilitating efficient electron transfer during HER. Consequently, we synthesized ternary FeCoNi-LDH/graphene composite by hydrothermal method and measured the HER performance in 1.0 M KOH electrolyte. We used X-ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), and transmission electron microscope (TEM) to determine the crystal structure and morphology of the composite. The results demonstrate that we successfully synthesized FeCoNi-LDH/graphene. In addition, Linear Sweep Voltammetry (LSV) were employed to confirm the HER performance. The overpotential and Tafel slope is -386.6 mV and 85.8 mV/dec, respectfully.

4:00pm TS1-2-MoA-8 One Step Fabrication of Highly Ordered Binder Free Vanadium Oxide Thin Film Cathode for Next Generation Micro Batteries, Ananya Bansal [ananya_b@ic.iitr.ac.in], Indian Institute of technology Roorkee, India; *Ramesh Chandra*, Indian Institute of Technology Roorkee, India

The increasing demand for microelectronics has significantly driven the advancement of thin film energy storage devices, specifically batteries. Till now, a range of materials have been investigated for lithium-ion batteries, with vanadium oxide emerging as a promising material. Vanadium oxides are known for multiple oxidation-reduction states during electrochemical reaction, hence, can promote multiple diffusion of Lithium ions resulting in high energy and power density. In this work, binder-free Vanadium oxide (V_2O_5) has been synthesized by reactive DC magnetron sputtering on aluminium foil substrate. Vanadium target (99.99% pure) is bombarded with high-energy Ar^+ ions which dislodge atoms from the vanadium surface. These ejected atoms then react with oxygen ions to form highly pure V_2O_5 and deposit onto a substrate, forming a thin film. The deposited layers were analyzed for their structural and surface morphology using XRD and SEM techniques. Highly ordered brick like nanostructures were observed during SEM analysis. X-ray photoelectron spectroscopy measurements were carried out to understand the chemical bonding of the cathode. The surface of vanadium oxide obtained from this binder-free approach helps us to create a high-quality cathode-electrolyte interface with high wettability (33.3°). Cyclic voltammetry (CV), galvanostatic charge-discharge (GCD) cycling, and electrochemical impedance measurements were used to investigate the capacity and cycling stability of the V_2O_5 cathode in 1 M lithium hexa-fluoro-phosphate. As a result, it can be interpreted that this binder-free technology can be used to fabricate efficient lithium free cathode for new generation thin film batteries.

4:20pm TS1-2-MoA-9 Research Coating Conductive Material on SiO_x @rGO Composite Materials as Anode Material in Lithium-Ion Batteries, Yi-Ling Chen [n56124155@gs.ncku.edu.tw], National Cheng Kung University (NCKU), Taiwan

With the advancement of technology, lithium-ion batteries have emerged as a future energy storage technology with the gradual development of electric vehicles. Silicon-based materials, due to their high theoretical capacity, energy density ($\sim 4200\text{mAh/g}$), and natural abundance, are considered as candidates for negative electrode materials in lithium-ion batteries.

In this study, our research team successfully prepared reduced graphene oxide (rGO) using the Hummer method and incorporated commercial SiO_x micron-sized powder to synthesize SiO_x @rGO composite material as an anode for lithium-ion batteries. The initial charge capacity was measured at 1487 mAh/g, with a discharge capacity of 1060 mAh/g, yielding an initial coulombic efficiency of 71%. After 40 cycles, the capacity retention remained at 91%. However, there are currently no theoretical studies addressing the lithiation process and lithium ion insertion/extraction mechanisms in SiO_x materials.

Therefore, in our study, we not only explore the use of SiO_x @rGO composite material as an anode to improve the theoretical capacity and energy density of lithium-ion batteries but also aim to enhance the electrical conductivity and electrochemical performance of the battery. Conductive materials such as copper, gold, and platinum will be deposited on the prepared SiO_x @rGO anode material. These conductive coatings will provide additional electrons, creating a driving force for lithium ion diffusion into the anode material during discharge to achieve charge conservation. This process is expected to enhance the capacity and cycling stability of lithium-ion batteries. We will characterize the materials using X-ray diffraction (XRD), scanning electron microscopy (SEM), energy-dispersive spectroscopy (EDS), and transmission electron microscopy (TEM). Furthermore, charge-discharge and cycling performance tests will be conducted on the lithium-ion batteries to investigate the effect of the conductive materials on their performance. Cyclic voltammetry will be

employed to observe the electrochemical reactions during charge and discharge cycles.

This study conducts a theoretical analysis of SiO_x @rGO composite material as an anode for lithium-ion batteries by coating it with conductive materials, aiming to provide valuable reference data for both commercial and academic purposes.

Topical Symposium on Sustainable Surface Engineering Room Town & Country C - Session TS3-TuA

Circular Strategies for Surface Engineering

Moderators: Marcus Hans, RWTH Aachen University, Germany, Nina Schalk, Montanuniversität Leoben, Austria

2:00pm **TS3-TuA-2 Scalable Solar-Thermal Synthesis of High-Yield Flake Graphite and Hydrogen**, Timothy S. Fisher [tsfisher@ucla.edu], University of California Los Angeles, USA

INVITED

Current industrial processes for power, fuel, and commodity production are responsible for massive, ongoing CO₂ emissions that adversely affect the stability of Earth's climate with potentially disastrous consequences. Increased use of hydrogen as a fuel and chemical building block promises to reduce CO₂ emissions in critical sectors, but contemporary hydrogen production technologies also involve high greenhouse gas emissions. This talk considers a process in which concentrated radiation from a simulated solar source converts methane and similar hydrocarbons to high-value synthetic flake graphite and hydrogen gas. Methane flows within a photo-thermal reactor through the pores of a thin substrate irradiated by several thousand suns at the focal peak. The methane decomposes primarily into hydrogen while depositing highly graphitic carbon that grows conformally over ligaments in the porous substrate. The direct heating of the porous substrate serves to capture the solid carbon into a readily captured and useful form while maintaining active deposition site density with persistent self-catalytic activity. The talk will cover topics including solar irradiation profile modeling and measurements, chemical kinetics, gas-phase diagnostics, material characterization, product yields, and solar-to-chemical efficiency.

2:40pm **TS3-TuA-4 Developing Next Generation Sustainable Flexible Food Packaging Materials**, Peter Kelly [peter.kelly@mmu.ac.uk], Manchester Metropolitan University, UK; Carolin Struller, Bobst Manchester Ltd, UK; Glen West, Manchester Metropolitan University, UK; Nick Copeland, Bobst Manchester Ltd, UK; Gwyneth Spence, Manchester Metropolitan University, UK

Flexible food packaging materials are complex surface engineered products that must meet demanding quality criteria yet be produced at very high volume and low cost. Until recently, typical flexible packaging material might consist of an inner heat sealable polyethylene (PE) film, then combinations of adhesives to hold the laminated structure together, inks for printing product details, a topcoat, a barrier layer and finally an outer polymer film, such as polyethylene terephthalate (PET). The barrier layer provides extended shelf life to the food product by preventing moisture and oxygen ingress, which spoils the product over time. Barrier layers can be organic layers (e.g. polyvinylidene chloride (PVdC)) deposited by wet chemical techniques, aluminium foil layers or as in the case here, either aluminium or aluminium oxide ('AlOx') coatings deposited by thermal evaporation techniques. These coatings are deposited at very high rates (line speeds are up to 1000m/min) and over very large areas (up to 4.85m wide x 100km long rolls) in roll-to-roll vacuum systems. Average barrier layer thicknesses are 40-50nm for Al films and 8-15nm for AlOx layers.

As a consequence of the mixed materials used in conventional flexible packaging, most products cannot be recycled and go to landfill or are incinerated. The increasing demand for sustainable packaging products has led Bobst and other companies in the packaging value chain (ranging from raw material producers and converters to brand owners and retailers) to develop new products that meet the criteria of 'recyclable, reusable or compostable'.

This paper describes progress towards mono-material polyolefin-based solutions for fully recyclable polymeric packaging and paper-based products, which are suitable to be processed in the existing paper recycling stream. In both cases, the Bobst oneBARRIER PrimeCycle PE product and the FibreCycle paper-based product provide high barrier performance and meet international recyclable standards. In addition to the development of these products, extensive life cycle analyses (LCAs) have been undertaken on each stage of the manufacturing process to allow accurate and comparable assessments to be made of the environmental impact and sustainability of the product.

3:00pm **TS3-TuA-5 PFAS Free Anti-Stick Coatings for Superior Electrosurgical Performance**, Noora Manninen, Oerlikon Surface Solutions, Liechtenstein; Julien Keraudy [julien.keraudy@oerlikon.com], Oerlikon Surface Solutions AG, Liechtenstein; Sanna Tervakangas, Oerlikon Surface Solutions, Finland; Klaus Boebel, Oerlikon Surface Solutions, Liechtenstein
Per- and polyfluoroalkyl substances (PFAS) are a large class of thousands of synthetic chemicals currently used in a wide variety of products (e.g. food packaging, cookware, textiles, medical devices, semiconductor components, batteries, among many others). PFAS contain carbon-fluorine bonds, which are one of the strongest chemical bonds in organic chemistry, meaning they are very attractive in different consumer products as they can resist to degradation. Nevertheless, the degradation resistance also persists once they are disposed. Currently PFAS are increasingly detected as environmental pollutants and some are linked to negative effects on human health, which has led to the current restriction proposal by European Chemical Agency (ECHA).

The restriction on use of PFAS will require the development of new solutions, which must fulfill health and environmental requirements. Medical devices are one of the main fields of use of PFAS, where PTFE based coatings are widely used, among many applications as anti-stick coatings in electrosurgical devices. In the current work existing coating solutions already in use for medical market and approved by regulatory authorities (e.g. FDA) have been tested (e.g. TiN, CrN, DLC, Parylene C) and compared to new coating solutions under research and development. The main goal is to obtain coatings with good anti-stick performance, which ideally can be re-used as multiple use devices, opposed to concept of single-use devices, which are discarded after each surgery generating large amount of waste. In order to fulfill the requirements for multiple use devices the coatings must stand multiple cleaning and sterilization cycles meaning they must have good corrosion properties as well as good abrasion resistance.

In the present study the coatings are characterized regarding their surface energy given that this surface property is connected with anti-sticking properties, and also functional tests are performed in a test set-up consisting of an electrosurgical unit (ESU) where coatings anti-stick performance is tested against pork liver. Additionally, the corrosion and abrasion resistance of the coatings are evaluated under autoclave and alkaline cleaning conditions and under abrasive cleaning test condition in order to resemble the lifecycle of multiple-use electrosurgical devices.

4:00pm **TS3-TuA-8 Design of Defect Structure in an Epitaxial VN Bilayer Film by Tailoring Nitrogen Concentration and Interfacial Strain**, Marcus Hans [hans@mch.rwth-aachen.de], Damian Holzapfel, RWTH Aachen University, Germany; Zhuo Chen, Erich Schmid Institute of Materials Science, Austria; Soheil Karimi Aghda, Michal Fečik, RWTH Aachen University, Germany; Daniel Primetzhof, Uppsala University, Sweden; Zaoli Zhang, Erich Schmid Institute of Materials Science, Austria; Jochen Schneider, RWTH Aachen University, Germany

A V_{0.48}N_{0.52}/V_{0.54}N_{0.46}(001) bilayer has been grown epitaxially on MgO(001) by reactive high power pulsed magnetron sputtering at a temperature of 400 °C in an industrial-scale deposition system. Based on ion beam analysis, atom probe tomography, X-ray diffraction, high-resolution transmission electron microscopy data as well as *ab initio* calculations, it is demonstrated that the defect structure is affected by the nitrogen concentration and interfacial strain. Strain at the MgO/V_{0.48}N_{0.52} interface is caused by a lattice parameter mismatch of ~2.3% as predicted by density functional theory. The experimentally determined lattice parameter difference is only ~1.3%, hence, the interfacial strain is partially relaxed by formation of misfit dislocations. Consequently, the dislocation density in V_{0.48}N_{0.52} is reduced from ~0.20 nm⁻² to ~0.10 nm⁻² within a distance of ~10 nm from the MgO/V_{0.48}N_{0.52} interface. The dislocation density is reduced to ~0.04 nm⁻² at the V_{0.48}N_{0.52}/V_{0.54}N_{0.46} interface and < 0.01 nm⁻² in the V_{0.54}N_{0.46} layer within a distance of ~35 nm from the interface due to strain relaxation. Based on the here presented findings, it is evident that control of the nitrogen concentration and interfacial strain allows for the design of layered architectures with a variation in dislocation density by two orders of magnitude.

4:20pm **TS3-TuA-9 Low Friction Sputtering Coatings, a Sustainable Option to Reduce Energy Consumption and Harmful Lubricant Usage**, Albano Cavaleiro [albano.cavaleiro@dem.uc.pt], University of Coimbra, Portugal

INVITED

From the more than 500 EJ of the World energy consumption, 20% regards losses due to friction in mechanical contacts¹. The obvious solution to decrease friction, the use of liquid lubricants, rises increasing concerns to

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the environment due to their harmful impact. Therefore, alternatives that can either provide a decrease of the friction in solid contacts or a reduction/removal of the usage of liquid lubrication, will have a significant and positive impact in both saving of energy and protection of the environment.

Low friction coatings were intensively developed in last decades as solutions for applications where liquid lubrication is restricted (space, food industry, vacuum,...) as well as a tool for removing either the usage of liquid lubrication or the extremely harmful additives of lubricant oils. As friction is a surface phenomenon, the main advantage of low friction coatings is that they can be applied over the currently used materials for mechanical applications without significant changes of the components and devices.

In this talk several examples related with the development and application of sputtering coatings in mechanical applications (moulding, cutting, forming,...) with main objectives of decreasing friction and reducing the harmful impact of oil lubricants, will be presented. The sliding mechanisms, in particular the understanding of tribolayers formation, will be addressed and connected to different concepts which were in the basis of the coatings development.

¹ K. Holmberg, A. Erdemir, Influence of tribology on global energy consumption, costs and emissions, Friction 5 (2017) 263–284

Topical Symposium on Sustainable Surface Engineering Room Palm 5-6 - Session TS2-WeA

(Photo)electrocatalysis and Solar/Thermal Conversion

Moderator: Arnaud Le Febvrier, Uppsala University, Sweden

2:00pm **TS2-WeA-1 Flexible Thermoelectrics: Transforming Wearables, Space Exploration, and IoT, André Pereira [ampereira@fc.up.pt],** University of Porto, Portugal **INVITED**

Flexible thermoelectric (TE) materials are at the forefront of advancing wearable electronics, space exploration, and the Internet of Things (IoT), offering a sustainable and efficient means of converting thermal gradients into electrical energy. Recent research has explored innovative designs and materials to overcome challenges in flexibility, efficiency, and scalability. A pivotal development is the radial flexible thermoelectric device powered by high-power laser beams, showcasing photo-thermoelectric conversion for wireless energy transfer. This approach provides a transformative solution for applications in space exploration, particularly for powering CubeSats and remote sensing systems.

Advances in hybrid thermoelectric materials have also driven significant progress. Nanostructured Bi_2Te_3 composites, integrated with polymer matrices like PVA, have demonstrated enhanced thermoelectric performance and printability. Devices fabricated with these materials achieve excellent mechanical flexibility and are well-suited for low-power wearable devices and printed electronics. The optimization of hybrid materials and ink formulations has enabled the realization of scalable, printable thermoelectric generators (TEGs) with customizable geometries.

Furthermore, the development of functional thermoelectric inks has opened avenues for high-throughput manufacturing of flexible μ -TEGs. These devices exhibit improved thermoelectric properties, mechanical stability, and adaptability to various substrates, ensuring seamless integration into IoT sensor networks and wearable platforms. The interplay of material innovations, device architecture, and advanced manufacturing techniques underscores the potential of flexible thermoelectrics in addressing global energy challenges while enabling novel functionalities in emerging technologies.

This work highlights the role of multidisciplinary approaches in transforming the capabilities of thermoelectric devices, paving the way for their adoption in dynamic environments and applications demanding autonomy and efficiency.

Acknowledge:

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Printed Flexible μ -Thermoelectric Device Based on Hybrid Bi_2Te_3 /PVA Composites

AL Pires, et al. ACS applied materials & interfaces 11 (9), 8969-8981

A Photo-Thermoelectric Twist to Wireless Energy Transfer: Radial Flexible Thermoelectric Device Powered by a High-Power Laser Beam

2:40pm **TS2-WeA-3 Alloy/Phosphate Heterostructure as High-Performance Hydrogen Evolution Reaction Electrocatalyst, Yung Hsun Yen [N56124210@gs.ncku.edu.tw],** National Cheng Kung University (NCKU), Taiwan; *Thi Xuyen Nguyen*, National Cheng Kung University (NCKU), Taiwan; *Jyh Ming Ting*, National Cheng Kung University (NCKU), Taiwan

With the rising demand for sustainable energy, the development of efficient electrocatalysts for the hydrogen evolution reaction (HER) has become increasingly important. Also, achieving cost-effective water electrolysis in industrial scale is crucial for large-scale green hydrogen production. In this study, we have investigated metal alloy/phosphate heterostructure HER electrocatalysts. Alloy is first synthesized using a two-step hydrothermal process, followed by thermal annealing. Phosphate is then electrodeposited on the surface of as-prepared alloy. The obtained catalyst demonstrates excellent catalytic activity toward HER with a low overpotential of 28.4 mV at 10 mA cm^{-2} and small Tafel slope of 42.1 mV dec^{-1} . Under a high current density of 500 mA cm^{-2} , the catalyst requires an

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only ultra-low overpotential of 186.3 mV. Stability tests using AEMWE having the heterostructure OER electrocatalyst are performed under 1 M KOH electrolyte and 1 M KOH + 0.3 M NaCl electrolytes. After 1000-h of test at 500 mA cm^{-2} , negligible voltage drops are demonstrated under both electrolyte conditions. The excellent HER performance and cost-effective of the synthesized catalyst is highly desirable for real water splitting for sustainable hydrogen production.

3:00pm **TS2-WeA-4 Ni-Co Based Catalysts for the Upcycling of Polyethylene Terephthalate, Ruei Chi Lin [a0979116476@gmail.com],** National Cheng Kung University (NCKU), Taiwan; *Thi Xuyen Nguyen*, National Cheng Kung University (NCKU), Taiwan; *Jyh Ming Ting*, National Cheng Kung University (NCKU), Taiwan

Plastic waste management represents a critical environmental issue. Electrochemical upcycling of polyethylene terephthalate PET waste into high-value chemicals has received great attention recently. However, the development of highly active and selective catalysts remains challenging. In this study, we have developed a noble metal-free Ni-Co based electrocatalyst, synthesized via a hydrothermal method, for ethylene glycol oxidation reaction (EGOR). The EG is derived from PET. With its high surface area and tunable electronic structure, the obtained catalyst exhibits an excellent potentials of 1.25 V and 1.31 V at current densities of 10 mA cm^{-2} and 100 mA cm^{-2} , respectively. PET is effectively transformed into potassium terephthalate with excellent Faradaic efficiency and selectivity under high current density. Meanwhile, zero-gap membrane electrode assembly closed-loop flow reactor has been used to achieve outstanding stability of PET upcycling in PET hydrolysis at 100 mA cm^{-2} . This work highlights the excellent potential for electro-reforming PET plastic waste into valuable chemicals with simultaneous reduced-cost hydrogen production.

3:20pm **TS2-WeA-5 Single Atom Ag Bonding between PF3T nanocluster and TiO_2 leads the Ultra-stable Visible-Light-Driven Photocatalytic H_2 Production, Tsan-Yao Chen, Fan-Gang Tseng,** National Tsing Hua University, Taiwan; *Jyh-Pin Chou*, National Taiwan University, Taiwan; *Sun Wei Tse*, National Tsing Hua University, Taiwan; *Jia-Yu Tsai [ym1015139@gmail.com],* National Taipei University of Technology, Taiwan

Atomic Ag cluster bonding is utilized to enhance the interface between PF3T nanoclusters and TiO_2 nanoparticles. At an optimized Ag loading of 0.5 wt% (Ag/ TiO_2), the Ag atoms are uniformly dispersed on the TiO_2 surface, generating a high density of intermediate states within the bandgap. This forms an efficient electron channel between the terthiophene groups of PF3T and TiO_2 in the hybrid composite (denoted as T@Ag05-P). The enhanced interface broadens the photon absorption bandwidth and facilitates core-hole splitting by enabling photon-excited electrons (from excitons in PF3T) to inject into the conduction band (CB) of TiO_2 . These features enable a remarkable H_2 production efficiency of 16,580 $\mu\text{mol h}^{-1} \text{g}^{-1}$ and exceptional photocatalytic stability, with no degradation observed under visible light exposure for 96 hours. Compared to the hybrid material without Ag bonding (TiO_2 @PF3T), the H_2 production yield and stability improve by 4.1-fold and 18.2-fold, respectively, representing the best performance among similar materials with comparable component combinations and interfacial reinforcement strategies. This innovative bonding approach opens new opportunities for advancing photocatalytic hydrogen production technologies.

3:40pm **TS2-WeA-6 Transition Metal-Based Electrocatalysts for Sustainable Oxygen Reactions in Green Energy Applications, Emma Björk [emma.bjork@liu.se],** Linköping University, IFM, Sweden **INVITED**

Water splitting and recombination are pivotal processes in the transition toward green, renewable, and fossil-free energy production. These reactions are limited by the kinetics of the oxygen reactions—the Oxygen Evolution Reaction (OER) and the Oxygen Reduction Reaction (ORR)—which creates a significant demand for efficient electrocatalysts. Efforts are focused on developing abundant, cost-effective alternatives to the noble metal catalysts currently in use. In this presentation, the possibility to use transition metal oxides, e.g. Co, Ni, and Mn oxides, as oxygen catalysts will be discussed.

The first part will cover multicomponent films, e.g. CoCrFeNi and MnCrFeNi , as catalytically active, corrosion-resistant coatings. The films were synthesized via magnetron sputtering and subsequently subjected to electrochemical activation through anodization, enhancing their catalytic activity towards both ORR and OER. Anodization also altered the ORR mechanism in CoCrFeNi and MnCrFeNi films, shifting it from a (2+1) electron pathway in as-deposited films to either a 4- or 2-electron pathway in anodized films. These changes are attributed to modifications in active

sites and film structure. Substituting Co with Mn slightly improved OER performance but did not affect the ORR activity significantly.

The films also demonstrated excellent corrosion resistance in alkaline and neutral chloride environments, attributed to the formation of a protective oxide layer. The corrosion performance was influenced by film composition and structure, particularly grain size. For example, lattice distortion in CoCrFeNi enhanced resistance in NaCl, while smaller grain sizes improved the corrosion resistance in KOH.

The second part of the talk focuses on increasing catalytic activity of transition metal oxides by introducing nanoporosity to enhance the number of active sites. Nanoporous materials, which often have specific surface areas exceeding 100 m²/g, were synthesized via hydrothermal treatment methods to create nanoporous MO_x (M = Cr, Fe, Co, Ni, Ce) and NiCo₂O₄ oxygen electrocatalysts. Optimizing pore size in nanoporous NiO revealed a critical balance between the number of active sites and the diffusion of reactants and products. NiO with a pore size of 3.3 nm achieved the lowest overpotential (335 mV at 10 mA/cm²), outperforming a commercial Ir/C catalyst under similar conditions.

The different ORR pathways on the various catalysts enable product selectivity, and we have designed electrochemical cells for an oxygen pump, hydroxyl radical generation, and H₂O₂ production using nanoporous transition metal oxides, air, water, and KOH.

4:20pm TS2-WeA-8 Bi-Based Photocatalysts Obtained by Reactive Sputtering for the CO₂ Photoreduction – from Thin Films and Composites to Nanoparticles, Angélique Bousquet [angelique.bousquet@uca.fr], Sara Ibrahim, Jean-Michel Andanson, Pierre Bonnet, Institut de Chimie de Clermont-Ferrand, France; Mireille Richard-Plouet, Institut des Matériaux, France; Maryline Le Granvalet, Institut des Matériaux de Nantes, France; Sébastien Roth, Audrey Bonduelle, Institut Français du Pétrole, Energies Nouvelles, France

To reduce the CO₂ emission into atmosphere is a major issue to mitigate the current climate change. Moreover, be able to photo-convert CO₂ into more valuable species and form clean solar fuels and molecules would be a step forward to the industry decarbonation. Among the photocatalysts investigated to photoreduce CO₂, Bi-based materials have demonstrated their interest to selectively form CO, a molecular building block which can further be used to obtain methanol, acetic acid, aldehyde and even fuels...

In this study, we investigated the deposition of Bismuth oxyfluoride thin films by reactive radiofrequency magnetron sputtering of a pure Bi target in Ar/O₂/CF₄ atmosphere. We demonstrated, that it is possible to obtain coatings of various crystallized compounds (Bi₇O₅F₁₁, BiO_{0.5}F₂, BiF₃...) depending on the injected flow rates of O₂ and CF₄ reactive gases. More interesting, is the possibility to form composites of these compounds with a controlled content of metallic Bismuth nanodomains by reducing the reactive gas flow rates. Hence, we obtained in one step heterojunctions that presents enhanced photocatalytic activities thanks to potential plasmonic effect. The composition, structure and morphology of these coatings were studied by XRD, Raman spectroscopy, XPS, TEM and SEM. Their optical properties, especially their band gap, were determined from UV-visible spectroscopy and ellipsometry. Experiments of photodegradation of pollutants into water shows that an optimum of metallic content has to be found to enhance the photocatalytic properties of the Bi-based materials^[1]. The CO₂ photoconversion measurements, performed at IFPEN, on these materials demonstrate a photon conversion efficiency close to the one of TiO₂ P25 from Degussa, but with a high selectivity to form CO (= 90% and 10% of H₂).

To go further, we now working on nanostructuration of these materials in order to increase the contact surface with CO₂ gas using an original method: the reactive sputtering onto liquid. If this technique was already investigated to form dispersion of metallic nanoparticles into liquid, we succeeded for the first time to use it in reactive mode to obtain dispersion of spherical, well-crystallized oxyfluoride nanoparticles with a mean size ranging from 6 to 8 nm and presenting a photocatalytic response^[2]. These particules may be dispersed on porous support paving the way of high surface specific area system for CO₂ photoreduction.

[1] S. Ibrahim, et al., 2023, hal-04037069v1.

[2] S. Ibrahim, et al., Nanoscale, 15, 2023, 5499 - 5509

Topical Symposium on Sustainable Surface Engineering Room Golden State Ballroom - Session TS1-ThP

Coatings for Batteries and Hydrogen Applications Poster Session

TS1-ThP-2 Y-doped $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ (Y-LLZO) Based all Solid-State Lithium Ion Battery Prepared by Colloidal Coating Processes, Yen-Yu Chen [yychen@mail.npust.edu.tw], Guang-Yi Yao, National Pingtung University of Science and Technology, Taiwan

All solid-state lithium ion batteries (ASSLIBs) were widely investigated due to safety issue and higher electrical performance. In this study, Y-doped $\text{Li}_7\text{La}_3\text{Zr}_2\text{O}_{12}$ (Y-LLZO)-based solid electrolyte coatings on the LiCoO_2 (LCO)-based cathode substrate with C/Si anode printed on the coatings were prepared. The Y-LLZO powders were synthesized by a solid-state reaction method. Several properties were analyzed including microstructures by scanning electron microscopy (SEM) and transmission electron microscopy, crystal phases by the X-ray diffraction (XRD) method, electrical performance by electrochemical impedance spectroscopy (EIS) and battery testing system. The Y-LLZO coatings after sintered at 1100°C for 12 h show highly dense configuration on the LCO-based cathode substrate. The thicknesses of the coating layers are around several to ten more micrometers. Only a few of pores can be found in the coating layers. The crystal phases after sintering were including the major LLZO garnet and a rare of $\text{La}_2\text{Zr}_2\text{O}_7$ phases. The interface between Y-LLZO and LCO grains shows slightly inter-diffusion behavior. The electrical conductivity of Y-LLZO is around $10^{-4}\sim 10^{-5} \text{ S}\cdot\text{cm}^{-1}$. The more details will be reported in the presentation.

TS1-ThP-5 PVD-Coated Interconnects for Solid Oxide Electrolysers, Giuseppe Sanzone [giuseppe.sanzone@teercoatings.co.uk], Teer Coatings Ltd, UK; Kun Zhang, University of Birmingham, UK; Susan Field, Hailin Sun, Teer Coatings Ltd, UK; Jangwoo Seo, Hyo Ki Hwang, In-sung Lee, E&KOA Co., Republic of Korea; Parnia Navabpour, Teer Coatings Ltd, UK

Achieving net-zero emissions by 2050 continues to be a significant challenge for the global energy sector. Hydrogen, and specifically green hydrogen can play a key role in decarbonisation, as it has the potential to be used as fuel for power and transportation. Green hydrogen can be produced in several ways using renewable energy sources like solar, wind or nuclear, through high- and low-temperature electrolysis, various thermochemical and photochemical processes. Water electrolysis is the most effective technique which is capturing the market's attention.

Amongst the electrolyser technologies, solid oxide electrolysis (SOE) are the most energy efficient. However, there are challenges related to their performance, lifetime, durability and cost, along with the scale-up from kW to MW level. The interconnect plays an important role as a current collector and a physical barrier that separates the electrodes between cells. It has to meet technical requirements such as matching thermal expansion coefficient to other (ceramic) layers, high thermal and electrical conductivities, formation of a dense low-resistive oxide layer in redox atmospheres, and high thermomechanical strength at elevated temperatures (600 to 900°C). The metallic interconnects employed in the SOC stack operated usually suffer high temperature corrosion and Cr-evaporation in the steam-rich environment at high temperature, leading to material failure of interconnects and degradation electrolysis stack. There is a need to control the chromium (VI) diffusion from the metallic interconnects and its poisoning of the air electrode to achieve increased electrolyser durability and performance.

This work presents conducting, protective spinel oxide coatings deposited by PVD method in order to reduce chromium evaporation from the interconnects. These coatings benefit from a dense structure as well as scalability, allowing high performance and making them suitable for commercialisation. The effect of coating thickness and composition on high temperature stability and chromium evaporation rate from ferritic stainless steel has been investigated.

TS1-ThP-6 Porous BiVO_4 Thin Films Deposited by Radiofrequency Co-Sputtering as Photoanode for H_2 Production by Water Splitting, Mathias Goutte, Angélique Bousquet [angelique.bousquet@uca.fr], Eric Tomasella, Institut de Chimie de Clermont-Ferrand, France; Guillaume Monier, Institut Pascal, France; Thierry Sauvage, CEMHTI, France

H_2 is considered as a potential new fuel which will participate to decarbonate the mobility sector. Unfortunately, this molecule is nowadays mainly formed from fossil gases, and so, does not meet criteria for the sustainable

development. Efforts are then engaged to develop new clean H_2 synthesis technologies such as water photo(-electro)lysis. However, this latter method still suffers from low global efficiency because of limited properties of photoanode. Thanks to its band gap in the visible range (near 2.4 eV) and its low valence band, Bismuth vanadate BiVO_4 is one of the most promising candidate for this application.

In this paper, we studied the deposition of BiVO_4 thin films by radiofrequency magnetron co-sputtering of Bi and V targets into Ar/O_2 atmospheres. By tailoring the target powers, we were able to deposit coatings with various V/Bi ratios (determined by Rutherford Backscattering Spectroscopy). Since these as-deposited films are amorphous, thermal post-treatments were used to crystallize them. Interestingly, this treatment leads also to the development of porosity into the films thickness (observed by SEM), which will be beneficial to increase contact surface area with water. After 2 hours at 450°C in air, XRD analysis shows that BiVO_4 in monoclinic phase is mainly formed. This phase could be associated to Bismuth or Vanadium oxides ones for non-stoichiometric films. The XPS also confirms these heterojunctions formation following the shift of binding energy positions. Analysis by ellipsometry and UV-visible spectroscopy shows, that the films exhibit direct band gaps between 2.4 and 2.6 eV, while flat band voltages from -0.05 to -0.13 V (vs RHE) are deduced from the Mott-Schottky technique. Hence, diagram with band positions can be drawn for each thin films, indicating that their valence band positions are convenient for O_2 production. Stoichiometric film, that exhibits the lower valence band, also presents the higher photo-current density of $0.05 \text{ mA}/\text{cm}^2$ at 1.3 V vs RHE and this current density remains high under irradiation for more than one hour, while significant drop of 75% has usually been reported for electrodes made from powder.

To go further, Bismuth metallic nanoparticles were added on the top surface of BiVO_4 thin film by sputtering the Bismuth target in pure Argon during very short times. The presence of metallic nanoparticles, thanks to heterojunction and plasmonic effect, highly enhances the measured photocurrent, keeping a good stability in time.

TS1-ThP-7 HiPIMS Deposition of Ti_xN Coatings for Oxygen Evolution Reaction Catalysts, Yi-Chao Tsai [ljesskoghjkg@gmail.com], National United University, Taiwan; Ying-Hsiang Lin, National United University, Taiwan; Siang-Yun Li, Thi Xuyen Nguyen, Chia Ying Su, Ruei Chi Lin, Jyh-Ming Ting, National Cheng Kung University, Taiwan; Wan-Yu Wu, National United University, Taiwan

Electrochemical reactions, particularly hydrogen and oxygen evolution reactions (HER/OER), are crucial for advancing clean energy technologies. However, current OER catalysts primarily rely on noble metals like Ir and Ru, which are expensive and less durable. Transition metal nitrides (e.g., Ti, Fe, Co, Ni) have gained attention due to their high conductivity and cost-efficiency. TiN , specifically, shows metal-like conductivity ($3.34 \times 10^{-7} \Omega\cdot\text{cm}$), strong resistance to acids/alkalis, oxidation, and chemical inertness, making it ideal for OER. In this study, High Power Impulse Magnetron Sputtering (HiPIMS) was used to deposit Ti_xN films on Ni foam, chosen for its high porosity (98%) and conductivity, to enhance the active surface area. HiPIMS, with its high plasma density and strong film adhesion, is superior to traditional DC sputtering, particularly for complex substrate structures. The Ti_xN film with 63.1 at.% Ti content showed an overpotential of 377 mV at $50 \text{ mA}/\text{cm}^2$ (η_{10}), a Tafel slope of 121.4 mV/dec, and a charge transfer resistance (R_{ct}) of 3.05Ω , outperforming commercial RuO_2 (421 mV). Further optimization of the Ti/N ratio revealed that a film with 52.6 at.% Ti and 47.4 at.% N had the best performance, achieving an overpotential of 333 mV, a Tafel slope of 97.8 mV/dec, and R_{ct} of 1.95Ω . This demonstrates that a near 1:1 stoichiometric ratio in TiN significantly enhances conductivity and electron transfer, thus improving OER efficiency. Preliminary analyses using EDX, XPS, XRD, TEM, and SEM suggest that adjusting the Ti/N ratio may impact the catalytic activity of the films. Based on the current test results, the optimized Ti_xN films show promising potential in 1 M KOH electrolyte, indicating their prospective application as cost-effective and durable OER catalysts.

TS1-ThP-8 Enzyme-Catalyzed Thin-Film Coatings for Bipolar Plates, Chiara Nenninger [c.nenninger@biotec.rwth-aachen.de], Marisa Sárria Pereira de Passos, Institute of Biotechnology, RWTH Aachen University, Aachen, Germany; Philipp Niemietz, Manufacturing Technology Institute (MTI), RWTH Aachen University, Aachen, Germany; Thomas Bergs, Manufacturing Technology Institute (MTI), RWTH Aachen University, Aachen, Germany; Fraunhofer Institute for Production Technology (IPT), Aachen, Germany; Ulrich Schwaneberg, Institute of Biotechnology, RWTH Aachen University, Aachen, Germany; DWI-Leibniz Institute for Interactive Materials e.V., Aachen, Germany

Thin-film coatings are applied to almost all material surfaces to enhance their physical and chemical properties, as corrosion resistance and conductivity. Protection of metal materials used in batteries and bipolar plates from highly corrosive environments using functional coatings can extend their lifetime and improve performance. Despite advances in coating technologies, challenges remain in achieving uniform surface functionalization, broad material compatibility, control over film thickness, scalability and sustainability.

Within this work, a biological method for the surface-confined polymerization of thin-film coatings using immobilized enzymes was developed. A fusion protein consisting of an enzyme, a linker and an adhesion-promoting peptide (AP) [1] was immobilized via dip- or spray-coating from an aqueous solution at room temperature and atmospheric pressure. The enzyme catalyzes the polymerization reaction, that “automatically” stops at approximately 30 nm. The self-termination of the polymerization reaction occurs when the immobilized enzyme becomes encapsulated by the coating, thereby controlling the film thickness.

The scalability of this method was demonstrated by coating a stainless-steel plate measuring $30 \times 100 \times 0.02$ cm. The performance of the bio-based coatings was assessed on different metal alloys used in bipolar plates for hydrogen fuel cells through an alternating corrosion test, including climate storage and salt spray test, an acid resistance test, a pencil hardness test and a pull-off adhesion test. The coatings exhibited sheet resistance values within the range of 109 – 8250 kΩ sq⁻¹.

This work presents a novel enzymatic coating approach for materials used in bipolar plates and battery applications that need protection from highly corrosive environments. The coating method is resource- and energy-efficient due to the use of enzymes as catalysts in aqueous environment, at room temperature and atmospheric pressure. The method has the potential to be transferred to other materials and coatings by engineering or exchanging the AP, the enzyme, or by selecting alternative monomers.

Reference

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TS1-ThP-12 Collaboration between Atomic Clusters of Co, Sn, Ni Hydroxides, Pt Atoms in Pd Nanoparticle Surface Boosts Outstanding Oxygen Reduction Reaction Performance, Jia-Yu Tsai [ym1015139@gmail.com], Po-Chun Chen, National Taipei University of Technology, Taiwan

The rational design and synthesis of heterogeneous interfaces with tailored structural and functional properties are highly sought to realize green energy technologies. In the present study, quaternary metallic heterogeneous nanocatalysts (NCs) consisting of Pt-cluster decorated CoOx-SnOy-NiOz-Pd hierarchical structures (namely CSNPP) are proposed with improved heteroatomic interactions for an oxygen reduction reaction (ORR) in alkaline medium (0.1 M KOH). The CSNPP NCs have been synthesized with different Pt contents (0.334, 0.836, and 1.672 wt%) by using a wet chemical reduction method on an active carbon (AC) support with simultaneous heterogeneous and homogeneous nucleation. Of special relevance, the mass activity (MA) of CSNPP-0025 (0.836 wt% Pt) and CSNPP-005 (1.672 wt% Pt) NCs is 23826.48 mA mg⁻¹ and 11099.71 mA mg⁻¹, which is 355.619 and 165.667-fold increased, respectively, as compared to that of the commercial J.M.-Pt/C catalyst (20 wt% Pt) at 0.85 V vs. RHE. Through intensive analysis of microscopy and spectroscopy results, we demonstrated that such enhanced ORR activities for the ultra-low dosage of Pt are mainly dominated by incorporation of Pt atoms into the defect sites of the Co-Sn-Ni-Pd surface. These Pt-atoms lower the adsorption strength for oxygenated species via electron confinement from adjacent

sites, resulting in enhanced splitting and relocation kinetics of subsequent oxygen molecules on the NC surface and thus ORR performance.

Topical Symposium on Sustainable Surface Engineering Room Golden State Ballroom - Session TS2-ThP

(Photo)electrocatalysis and Solar/Thermal Conversion Poster Session

TS2-ThP-6 Perovskite Solar Cell with Potassium Chloride Treated SnO₂ Electron Transport Layer for Increased Efficiency, Akhil Prio Chakma [akhilprio.chakma@udc.edu], Biplav Dahal, Tewelde Semere, Hongmei Dang, University of The District of Columbia, USA

Perovskite solar cells (PSCs) have emerged as a promising candidate for next-generation photovoltaics due to their low fabrication cost and high-power conversion efficiency (PCE). However, recombination losses and charge transport issues at the interface between SnO₂ electron transport layer (ETL) and perovskite absorber are hindering the performance improvement. The SnO₂ surface often has oxygen vacancies and other defects that act as trap sites for electrons. These defects can lead to charge recombination, reducing the efficiency of charge extraction. This study demonstrates that potassium chloride (KCl) surface treatment of SnO₂ helps passivate these surface defects. Potassium ions (K⁺) can fill oxygen vacancies, reducing trap density, mitigating recombination losses, and decreasing hysteresis in the current-voltage (I-V) characteristics. Characterization using scanning electron microscopy (SEM), atomic force microscopy (AFM), kelvin probe force microscopy (KPFM) confirmed better surface morphology and larger grain sizes on KCl treated SnO₂ and the corresponding perovskite layer. X-ray diffraction (XRD) analysis further revealed enhanced crystallinity, which is evident by intense diffraction peaks and reduced full-width half maximum (FWHM) compared to control samples. Photovoltaic performance measurements demonstrated improvements in device performance after KCl treatment. The best performing KCl based PSCs showed a PCE of 21%, fill factor of 77%, open-circuit voltage (V_{oc}) of 1.08V, and short-circuit current density (J_{sc}) of 25 mA/cm². The KCl based PSCs demonstrated that average efficiency is about 25% higher than control samples. These results highlight the effectiveness of KCl surface treatment in enhancing charge extraction, enhancing crystalline, reducing recombination losses, and improving overall device performance, making it a promising strategy for advancing high-efficiency PSCs.

Keywords: Perovskite Solar Cells, Electron Transport Layer, Efficiency, Atomic Force Microscopy, Kelvin Probe Force Microscopy, Scanning Electron Microscopy, Forward Width at Half Maximum.

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Su, Chia-Ying: TS1-2-MoA-4, 2

Sun, Hailin: TS1-ThP-5, 8

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Tervakangas, Sanna: TS3-TuA-5, 4

Ting, Jyh Ming: TS2-WeA-3, 6; TS2-WeA-4, 6

Ting, Jyh-Ming: TS1-2-MoA-4, 2; TS1-ThP-7, 8

Tomasella, Eric: TS1-ThP-6, 8

Tsai, Jia-Yu: TS1-ThP-12, **9**; TS2-WeA-5, **6**

Tsai, Yi-Cho: TS1-ThP-7, **8**

Tse, Sun Wei: TS2-WeA-5, 6

Tseng, Chung-Jen: TS1-1-MoM-3, 1

Tseng, Fan-Gang: TS2-WeA-5, 6

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Wang, Chen-Hao: TS1-2-MoA-3, 2

Wang, Chih-Liang: TS1-1-MoM-7, **1**

Wang, Ke-Hsing: TS1-2-MoA-2, 2

Wang, Sheng Chang: TS1-2-MoA-5, 2

West, Glen: TS3-TuA-4, 4

Wu, Fan-Bean: TS1-2-MoA-4, 2

Wu, Hung-I: TS1-2-MoA-4, **2**

Wu, Wan-Yu: TS1-2-MoA-4, 2; TS1-ThP-7, 8

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Yao, Guang-Yi: TS1-ThP-2, 8

Yen, Yung Hsun: TS2-WeA-3, **6**

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Zhang, Kun: TS1-ThP-5, 8

Zhang, Zaoli: TS3-TuA-8, 4