Topical Symposia
Room Town & Country B - Session TS3-WeA
Electrochemical Cells – Hydrogen and Batteries

Moderators: Nazlim Bagcivan, Schaeffler Technologies GmbH & Co. KG, Germany, **Klaus Böbel**, Bosch GmbH, Germany

3:20pm **TS3-WeA-5 Current and Future Trends in Materials for Advanced Lithium Batteries**, *O. Kahvecioglu, **Carrie Siu (b294370@anl.gov)**,* Argonne National Laboratory, USA **INVITED**

The story behind lithium-ion batteries is nothing less than a quest for a new better performing materials and more reliable, safer devices. As far back as the late 1970s, a team of pioneering scientists began research on an invention that is known today as the lithium-ion battery or LIB. This rechargeable electrical energy storage device powers everything from hand-held electronics to power tools to electric vehicles and, in the near future, possibly even large vehicles and aircrafts. In 2019, the three brilliant minds behind LIB development, John B. Goodenough, M. Stanley Whittingham, and Akira Yoshino were recognized for their discovery with the award of the Nobel Prize in Chemistry. Like any other great discovery, early LIBs were not perfect. The first experiments that used electrodes made from titanium disulfide and lithium metal were less than successful. After these early batteries short-circuited and caught fire, it was decided to halt the experiments. Not for long. John B. Goodenough came up with another idea. In the early 1980s he substituted lithium cobalt oxide (LCO) for the cathode instead of titanium disulfide. This new material was so successful that modern-day cell phone batteries still use it.

To satisfy market demands, the quest for new materials rages on. Although Li-ion batteries are proven and reliable technologies, they are not perfect, and suffer from performance degradation over time, limited shelf life and most importantly, some hazards associated with their use. Scientists and engineers are constantly making improvements to mitigate these issues, however performance decay and thermal runaways have not entirely been solved. Most of today's research effort is focused on cathode active materials. Coating and doping are the most frequently used techniques to improve material performance. Atomic layer deposition (ALD), for example, is by far most the popular technique for depositing nano-scale conformal layers on powder surfaces.

Current and future battery materials development for electric vehicles (EVs) must address the range limits (longer), cycle performance (stable), energy density (higher) and safety (flammability). Achieving all of these parameters at the desired level with a single material is challenging. Li-ion battery fires seen all over the world drive battery researchers to discover safer materials. One promising technology is the all solid state battery (ASSB), which can potentially address all these issues. Massive efforts seek to address the interfacial problems between the cathode and electrolyte.

The presentation will discuss current trends in battery materials.

4:00pm **TS3-WeA-7 Application of Bipolar Hipims to Enhance the Durability Performance of Carbon Coatings in Metallic Bipolar Plates**, *J. Santiago , I. Fernandez, **Pablo Diaz-Rodriguez (pablo.diazr@nano4energy.eu)**,* Nano4Energy, Spain*; M. Panizo, M. Morales-Furio, C. Molpeceres,* Technical University Madrid, Spain*; J. Sanchez-Lopez,* CSIC-University Sevilla, Spain*; L. Mendizabal,* Tekniker, Spain*; G. Sevilla, M. Sanchez, N. Rojas,* Spanish Hydrogen National Center, Spain

Metallic bipolar plates (BPPs) are a promising candidate to replace conventional graphite BPPs due to higher power density and lower costs in proton exchange membrane fuel cells (PEMFCs). However, great challenges still exist for the application of metallic BPPs since they are working in acidic, humid, warm and polarized environment that reduce the lifetime of BPPs. The application of coatings is essential to enhance interfacial conductivity and corrosion resistance.

In this study, four different metal-doped amorphous carbon coatings (a-C:Cr, a-C:W, a-C:Nb and a-C:Ti) have been deposited by bipolar HiPIMS on stainless steel. The influence of HiPIMS parameters on coating-substrate interface, as well as the coating properties have been evaluated. SEM and TEM microscopy have been used to evaluate the coating interface. Raman analysis has been carried out to analyze the influence of metal content on carbon structure. The sp3-sp2 ratio has also been assessed with EELS spectroscopy. XPS analysis was used to evaluate the formation of metal carbides. Potentiodynamic and potentiostatic tests have been conducted to evaluate the corrosion resistance of the coated samples. Interfacial contact resistance (ICR) has been measured before and after corrosion tests.

Coatings deposited by bipolar HiPIMS improve coating-substrate contact interface and allow optimizing sp3-sp2 carbon structure, reducing ICR and enhancing corrosion resistance, as compared with carbon coatings deposited by conventional sputtering techniques. The results show that coatings follow the requirements established by DoE and are of great potential for application in PEMFC.

4:20pm **TS3-WeA-8 Coatings for Fuel Cells and Electrolyzers: From Materials to Processes, Challenges and Opportunities**, ***Etienne Bouyer (etienne.bouyer@cea.fr)**,* Commissariat à l'Energie Atomique et aux Energies Alternatives (CEA), Grenoble, France **INVITED**

Hydrogen technologies are booming according to the benefit such technologies can bring for decarbonisation of as an example energy intensive industry and mobility sectors.

One has to distinguish between hydrogen conversion to produce electricity and hydrogen production in itself for further valorization of this carbon free fuel. The first topic concerns fuel cells for electricity generation from hydrogen and oxygen whereas the second topic is related to electrolyzers that allow to produce clean hydrogen through water splitting. Both electrochemical devices are based on a multilayer system.

The first illustration relates to fuel cell that convert the chemical energy contained in a fuel into electrical energy. As all electrochemical devices, a fuel cell is composed by two electrodes (anode and cathode) separated by an electrolyte. Between the two electrodes, ions pass through the electrolyte (ionic conductor and electronic insulator). Fuel cell is an open electrochemical generator (unlike batteries that are closed systems). Proton Exchange Membrane Fuel Cell (PEMFC) is a fuel cell operating at around 60 to 80°C and, to maintain a reasonable kinetic noble-metals catalyst are needed.

The second illustration focuses on high temperature electrolyzers that are made of multilayer ceramic materials. It has the same structure (anode/electrolyte/cathode) than a PEMFC. The hydrogen production reaction is not spontaneous, therefore electrical energy must be supplied to the system to produce hydrogen in an electrolyzer. Such system operate at high temperature (600-800°C): increasing the temperature decreases electricity demand thanks to thermodynamics and improves electrochemical kinetics.But limitations due to materials are occurring.

An overview of materials as well as associated processes to shape such components as layers or coatings will be presented and discussed. A special emphasis will be put on the remaining challenges (which slow down development of such technologies) and on the potential solutions. This contribution will also pay attention on the use of the so-called critical raw materials, on the way to minimize their content or -even better- to substitute them by more abundant materials and to save material through an optimization of the shape forming processes.

5:00pm **TS3-WeA-10 Electrochemically Stable PVD Coatings With Low Interfacial Contact Resistance for Proton Exchange Membrane Electrolyzer Bipolar Plates**, ***Nathan Kruppe (kruppnth@schaeffler.com)**, E. Schulz, M. Öte, N. Bagcivan, J. Hackner, S. Rüth,* Schaeffler Technologies GmbH & Co. KG, Germany

In the scope of worldwide energy transition, the industrial availability of alternative energy sources is increasingly becoming the focus of attention - not least due to urgent legislative requirements. In the proton exchange membrane water electrolysis (PEMWE) water is electrochemically decomposed by an applied current. In this way, hydrogen is produced. PEMWE is characterized by its high-power density, the lack of hazardous chemicals and - a major advantage for the production of green hydrogen in particular - its ability to follow load changes almost instantaneously.

The core of the electrolyzer is the stack, in which numerous cells are stacked and interconnected via bipolar plates. The load collective acting on these bipolar plates is particularly harsh. Under warm and humid conditions, high electrochemical potentials, simultaneously low pH values, i.e. acidic environment as well as oxygen formation on the anode side and hydrogen formation on the cathode side, the materials are exposed to corrosive attacks on the one hand and hydrogen embrittlement on the other. The use of expensive solid materials such as titanium is not sufficiently suitable for the large series production of scalable, efficient, durable and robust PEMWE electrolyzers. Especially on the anode side, corrosive loading on stainless steel leads to reduced performance of the entire stack.

Surface technology offers a solution when stainless steel, which is significantly less expensive than titanium, is protected from corrosive attacks and hydrogen embrittlement by thin high-performance coatings. At the same time, a low contact resistance can be achieved in the long term. Within the scope of this contribution, it will be shown which requirements are placed on coating systems for PEMWE bipolar plates in order to realize electrochemical stability on the one hand and a sufficiently low interfacial resistance on the other hand. Results will be presented which prove the high potential of Schaeffler Technologies coating solutions for this application.

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