Scalable electrochemical strategies for preparation of supported catalysts for electrochemical energy conversion

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Electrochemistry plays an important role in energy conversion and storage, particularly in characterizing active materials used in fuel cells, electrolyzers, and batteries. However, electrochemical principles are crucial not only for characterization and quality control but also for the medium and large-scale production of electrocatalytic materials. Direct electrodeposition of active materials on conductive substrates is a straightforward strategy to produce electrodes for systems with liquid electrolytes, like alkaline water electrolyzers. On the other hand, active materials for systems employing solid membrane electrolytes are typically prepared in powder form and deposited onto porous substrates through methods such as screen printing, dipping, or spray coating using suitable suspensions. While these approaches are convenient for laboratory-scale membrane-electrode assembly preparation, they present challenges that must be addressed when considering production scale-up.

In addition to conventional preparative chemistry variables like concentration, temperature, pH, and agitation, electrochemistry offers further process control through parameters such as current density, potential, and their variation in time, including pulse and alternating polarity profiles. The broad selection of parameters makes electrochemical routes ideal for finely tuning material properties while ensuring excellent reproducibility. Direct electrochemical deposition routes enable the deposition of active material on both rigid and soft substrates, resulting in improved adhesion essential for electrical contact and prolonged catalytic activity. All this comes with the great scalability potential, which is vital for accelerating the deployment of hydrogen technologies on a global scale.

Proton-exchange membrane (PEM) and anion-exchange membrane (AEM) electrolyser and fuel cell technologies are based on metallic catalysts supported by various carbon materials (M@C). Direct electrodeposition of M@C materials can be achieved using oxidized form of carbon material, such as graphene oxide or oxygen-functionalized carbon nanotubes, as a precursor for electrophoretic deposition of metallic nanoparticles on the corresponding reduced form (e.g., reduced graphene oxide or carbon nanotubes). Alternatively, oxygen-functionalized carbons can be cast onto gas diffusion layer (GDL) and galvanostatically or potentiostatically reduced with simultaneous metal deposition. In the latter approach, metal precursors may be dissolved in the deposition bath, or absorbed into the cast film, and subsequently reduced in an inert electrolyte. One step catalyst electrodeposition can also be carried out directly onto preformed microporous layer of the GDL. This presentation will summarize direct electrochemical routes for preparing of active electrodes for membrane-based technologies, focusing on their scalability potential to medium or large-scale production. Additionaly, a brief discussion on electrochemical methods for modification of electrocatalysts on rigid substrates, utilized in aqueous electrolyte technologies, will be included.