Operando Monitoring and Insights for Hydrogen Production via Electrolysis

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Today, climate change and energy security are among the most important issues in the world [1]. To address the requirements of the global low-carbon transition, pressure is on to develop green hydrogen energy sources for the fast phase-out of fossil-fuel production [2]. Therefore, it is of great interest to develop better green hydrogen systems with low cost, high efficiency, extended durability, and high yield. This requires learning the art of hydrogen evolution, transport, and storage steps. Electrolysis is highly promising method for green hydrogen production yet several challenges need to be overcome. *Operando* techniques can offer in-situ monitoring and real-time observation of water electrolysis including the principles of reaction mechanisms, interfacial properties, structural changes of the active sites, electron and ion transfer, gas and water transport properties, and degradation mechanisms.

The present study provides insight into the current progress in *operando* analysis of electrolysis for hydrogen production. Specifically, we provide an overview of the recent advances in imaging methods of X-ray and neutron radiography, and micro-computed tomography; Infrared, Raman, X-ray absorption, photoelectron and electrochemical impedance spectroscopies (Figure 1). The operational principles of these techniques; temporal, spatial and spectral ranges of their applications; and limitations in monitoring and analyses are discussed in detail as well. In addition, reactions that occur in these systems, mechanisms that are taking place, and resultant system durability are presented. Finally, we recommend future directions in operando characterization for enhancing live monitoring of reactions, transport phenomena, and degradation mechanisms in hydrogen production processes [3].

The presented *operando* techniques can provide answers to clarify the chemical and physical processes occurring and help to develop the next generation of electrolysis devices. The cost of H_2 production from water electrolysis is still prohibitively high (3-7.5 USD/kgH_2) compared to other methods. In this respect, new *operando* techniques can have a significant impact on developing new classes of materials and architectures paving the way for the widespread application of green hydrogen production.

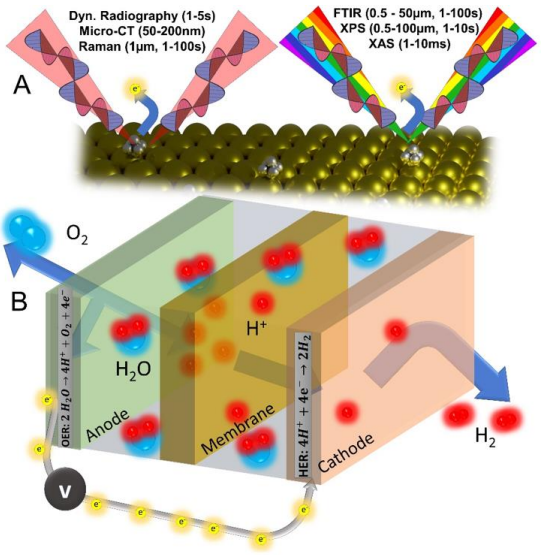

Figure 1. Schematic of artist rendering of (A) *Operando* techniques with their temporal and spatial resolutions. (B) Main electrolysis reactions and a typical system cell structure [3].

References

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