Realizing Hydrogen Economy and Rethinking Catalyst Layer Design: Interplay between Activity and Durability for Polymer Electrolyte Fuel Cells and Electrolyzers

The U.S. has pledged to decarbonize its economy by 2050. Decarbonization of transportation sector is critical to achieve net-zero emissions economy by 2050. Department of Energy (DOE) has issued Hydrogen Shot aiming to produce 1 kg of hydrogen for $1 in 1 decade. This '111' target is ambitious, as currently challenges of electrolyzers cost, durability and scale-up to MW scale need to be addressed. Proton exchange membrane water electrolyzers (PEMWEs) are promising technologies to reach these targets. The widespread deployment of these technologies is stifled today by high catalyst cost, high catalyst loadings and material properties that affect the complex two-phase transport processes consequently resulting in lower voltage efficiency. The anode catalyst for oxygen evolution reaction (OER) that is used in PEMWEs is IrOx, which precious metal catalyst that is not Earth abundant and expensive.

Once produced, hydrogen will be utilized in various industries, including manufacturing and it can serve as a fuel for various applications, including polymer electrolyte fuel cell (PEFCs). These technologies have advanced to reach the commercialization stage with more automotive manufacturers announcing new PEFC-based light and heavy-duty vehicles. The main advantage of the PEFCs is that they have zero emissions and produce only water. Using the DOE cost-breakdown for the 80-kW_{net} stack for light-duty vehicles, the cost of precious metal electrocatalysts remains almost unchanged as production rate increases to 0.5 M PEFC stacks per year. The cost of the electrocatalysts amounts to 31% of stack cost, for 0.5 M systems per year production rate. Platinum (Pt) or Pt-alloys are used as electrocatalysts for the oxygen reduction reaction (ORR) on the cathode side and the hydrogen oxidation reaction (HOR) on the anode side of PEFCs. Pt or Pt-alloy electrocatalysts are dispersed as nanoparticles onto a carbon-black support. DOE set a target of reducing Pt loading to 0.125 mg cm^{-2} to achieve the goal of \$12.6 kW_{net}^{-1} for a stack with power density target of 1.8 W cm^{-2}.

This presentation will summarize my group's recent efforts within the two main directions for the catalyst layer design for electrolyzers and fuel cells: 1) catalyst durability studies, via advanced characterization, 2) catalyst-ionomer interfaces understanding during the device lifetime and its impact on activity and durability. Using methodology of electrochemical characterization, including CO-displacement/stripping, double layer capacity studies, oxygen transport resistance measurements, and others, along with the computational modeling and advanced material characterization (synchrotron and lab-scale), we aim to build comprehensive understanding of transport properties, water and oxygen management and interfacial properties during the PEFCs' and PEMWE's lifetime.