SEMS: RESEARCH PROJECT DESCRIPTION

1. Project Background and Description

Electrocatalytic hydrogen production from mild media

The deployment of water electrolysis is challenging to be economically competitive (£ 7~7.5 kg^{-1} H_2) compared to steam reforming (£ 1.5~1.7 kg^{-1} H_2), due to the low hydrogen generation rate, high energy consumption and high-cost electrolysers. Besides, this technology is difficult to be applied under high current densities for rapid gas generation, due to the rapid increase of overpotential and the insufficient mechanical/chemical stability of electrocatalysts under large gas evolution rate. The hydrogen production in acidic media via polymer electrolyte membrane (PEM) electrolysis is an emerging and partially established technology, which delivers the advantages such as compact design, high current densities (>2 A cm^{-2}), high energy efficiency (80~90%) and high purity of H_2 production (>99.99%). However, the state-of-the-art electrocatalysts for PEM electrolysis are mainly based on expensive noble-metal elements such as Pt/Pd for hydrogen evolution reaction (HER) and IrO_2/RuO_2 for oxygen evolution reaction (OER). In addition, the PEM stack accounts for 30~40% of the overall system cost, thus further hindering its large-scale application. To improve the commercial availability of water electrolysis, it is necessary to address the challenges in new materials discovery (e.g., non-noble metal-based electrocatalysts), understand the fundamental mechanism (e.g., reaction mechanisms and kinetics, optimum working conditions, electrolyser failure mechanisms), and develop new types of devices (e.g., scale-up strategies, durability improvement, and cost reduction).
The project will develop robust and cost-effective self-standing electrocatalysts by using transition metal derivatives for both OER and HER that can function for splitting mild electrolytes (including industrial waste water). The knowledge gained will provide rational design strategies of cheaper and more reliable technologies that will have significant impacts on the environmental sustainability and renewable energy conversion.

2. Project Scope

- Design of hydrogen and oxygen electrocatalysts
- Evaluate the electrocatalyst performance in mild media
- Understand the structure-function relationships

3. Desired Skills from the Student

Materials synthesis

Materials characterization

Electrochemistry

4. Supervisory Team

Primary: Dr. Guanjie He

Secondary: Dr. Ana Sobrido