Introduction

Hydrogen gas (H_2) has the potential to be a sustainable energy carrier, as it has a high energy density, does not release CO_2, and is a feedstock chemical in various industries. Unfortunately, H_2 is mainly produced from fossil fuels by steam methane reforming, naphtha reforming, and coal gasification.[1], [2] A promising alternative is water splitting through electrolysis, which produces H_2 and O_2 via the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER), respectively. As a major advantage, this method does not release CO_2 or other volatile by-products. Commercial water electrolysis methods are alkaline electrolysis and PEM (proton exchange membrane) electrolysis. The advantages of PEM electrolysis are higher energy efficiency, quick response, and scalability. However, the used catalysts for the HER and OER in PEM electrolysis are Pt and IrO_2, respectively, which are both expensive and low-abundance materials.[3]

Methodology

In the CLEANH2 project, we tackle these challenges. The aim of this PhD is to select, synthesize, characterize, and evaluate earth-abundant electrocatalysts for both HER and OER. The focus is on metal sulfides for HER and metal oxides for OER. Molybdenum disulfide (MoS_2) is a widely known alternative catalyst for the HER due to its high catalytic activity and high stability.[4] Other sulfides such as Fe sulfides, were also found to be active as HER catalysts.[5] This implies that a whole range of mixed metal sulfides may have a catalytic performance and stability that outperforms the more established materials. Finding an earth-abundant alternative for the OER is much more challenging. This is caused by the difficult kinetics of the OER and the strong oxidative and acidic environment on the OER side of PEM electrolyzer.[6] A material is needed that has good catalytic activity for the OER and is stable against oxidation in acidic environments. Therefore, metal oxides with more abundant metals were selected as replacements for IrO_2.

Discussion

These materials were synthesized via hydrothermal synthesis routes. The synthesized materials were characterized using X-ray diffraction (XRD), Raman spectroscopy, and scanning electron microscopy (SEM) to investigate their morphology and crystal structure. The catalytic performances of the synthesized materials were evaluated with linear sweep voltammetry (LSV) using a three-electrode cell.

Conclusions

In our study, we have explored the potential of earth-abundant electrocatalysts for hydrogen production. Our initial choice of $Fe_2(MoO_4)_3$ for the oxygen evolution reaction did not yield the expected catalytic activity. Nevertheless, the synthesized Fe and Mo sulfides have demonstrated promising catalytic activity for the hydrogen evolution reaction. We will continue our search for alternative materials for the oxygen evolution reaction and further evaluate the stability and efficiency of these promising Fe and Mo sulfides. As we progress, we are optimistic about the potential impact of our research on the advancement of clean and sustainable energy technologies.

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