Magnetic field-enhanced electrochemical oxygen evolution reaction using Co_3O_4/$BaFe_{12}O_{19}$ co-catalyst system

Dorottya Szalay[1], Amy Radford[1], Chen Wu[2], Shik Chi Edman Tsang[1]*
[1] *Wolfson Catalysis Centre, Department of Chemistry, University of Oxford, Oxford, OX1 3QR, United Kingdom*
[2] *School of Materials Science and Engineering, State Key Laboratory of Silicon and Advanced Semiconductor Materials, Zhejiang University, Hangzhou 310027, China*
* edman.tsang@chem.ox.ac.uk

Introduction

In order to help reduce the effects of global warming and climate change, lot of scientific attention has been put towards finding a clean fuel source. Hydrogen stands out as an idea; option due to its high energy density (143 MJ/kg, which is three times that of liquid hydrocarbons) and its combustion byproduct, water, making it a zero-carbon emission energy source. [1] However, hydrogen production remains largely dependent on non-renewable sources. Most hydrogen is generated through coal gasification and steam-methane reforming, while a more sustainable method—electrocatalytic water splitting—accounts for only 3-5% of hydrogen production due to its high energy requirements. [2] This water-splitting process involves two half-reactions: the hydrogen evolution reaction (HER) and the oxygen evolution reaction (OER), with the latter posing a significant bottleneck. OER is a complex, four-electron process that demands high overpotentials, leading to slow reaction kinetics. [3]

This research investigates the use of Co_3O_4 electrocatalysts with $BaFe_{12}O_{19}$ magnetic co-catalysts as a highly efficient system for electrochemical OER. Research has shown that OER is a spin-related electron transfer where controlling the spins of intermediate oxygen radicals can result in more efficient production of triplet molecular oxygen. [4] This project aims to take advantage of the magnetic properties of barium ferrite and combine them with stable and corrosive-resistant cobalt oxide to create improved OER electrocatalysts under applied external magnetic fields.

Results and Discussion

Five different systems were investigated: pure Co_3O_4, pure $BaFe_{12}O_{19}$ mixed Co_3O_4/$BaFe_{12}O_{19}$ with ratios of 1:0.5, 1:1 and 1:1.5, keeping the amount of active Co_3O_4 catalyst constant. Chronoamperometry measurements with magnetic pulses at 2 V vs RHE were conducted to evaluate the catalytic properties of these systems and to investigate the effects of applied magnetic fields at various strengths (200 mT, 400 mT and 800 mT) and results are shown on Figure 1a. Increasing the amount of barium ferrite results in lower current densities, as it decreases the exposed electrochemically active surface area of cobalt oxide. However, the relative magnitude of the magnetic effect increases up to the 1:1 ratio sample, then decreases as the amount of active catalyst becomes less than that of the co-catalyst (Figure 1b). Therefore, with a focus on spin-pinning, this research investigates the combined effects of spin-pinning, magnetohydrodynamics and Lorentz forces to better understand how external magnetic fields can enhance electrochemical water splitting.

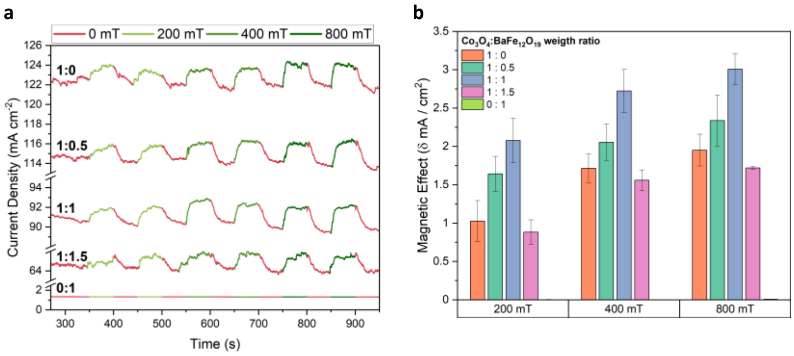

Figure 1. a) . Pulsed magneto-chronoamperometry results of the 5 systems with magnetic pulses: 200 mT (light green), 400 mT (medium green) and 800 mT (dark green). Note that barium hexaferrite shows no catalytic activity. b) Size of magnetic effect in chronoamperometry tests.

Significance

This project examines the impact of an externally applied magnetic field on electrochemical reactions, a rapidly growing area in chemistry with substantial gaps in the existing literature. This study delves into the fundamental chemical principles underlying magneto-electrochemistry and expands the experimental framework by investigating the use of a magnetic co-catalyst to enhance electrochemical activity of OER.

Materials and Methods

Cobalt oxide was synthesized through a two-step method. Barium hexaferrite was synthesized *via* a sol-gel method. Resulting powder samples were characterized by PXRD and SQUID. Catalyst materials were suspended in ethanol with 5% Nafion binding agent and drop-casted onto carbon paper. These were used in a standard 3-electrode system with Hg/HgO reference electrode and Pt counter electrode in 1 M KOH. Pulsed magneto-chronoamperometry measurements were recorded at constant potentials and are presented here with reference to the reversible hydrogen electrode (vs RHE). External magnetic field was applied using an electromagnet.

References

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