Green H_2-Fuel: Magnetic Effects on Water-Splitting

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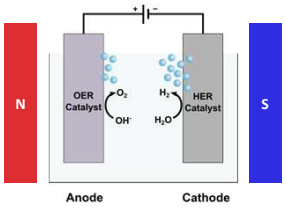
Motivation

Magnet | Green Electricity | Water | H_2 Fuel = Power

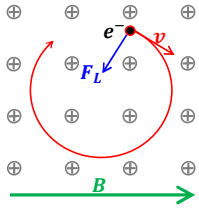
- Green H_2 fuel offers a clean and sustainable way to power the world
- Electrocatalytic water-splitting: using only electricity and a catalyst, water can be split into H_2 and O_2 ($2\ H_2O \rightarrow 2\ H_2 + O_2$)
- To improve the efficiency of H_2-production, external energy sources can be imposed on the process, such as magnetic fields



Theory

Magnetic fields can influence electrocatalysis in many ways. This has often been reported to improve H_2-production, generally by **increasing rate of charge carrier movement** through:

Lorentz Force



Lorentz force acts upon moving charges in a magnetic field.

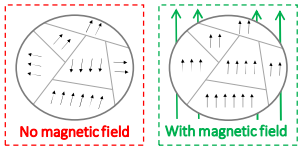
In catalysis, Lorentz force can influence:

- electrical resistance in a particle/electrode
- mass transport via magnetohydrodynamics

$$\vec{F_L} = q(E + \vec{v}\vec{B})$$

F_L = Lorentz force; q = charge of free carrier; E = electric field; v = velocity; B = magnetic field

Spin Polarisation



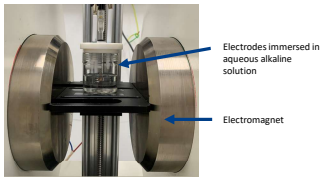
Schematic of electron spin alignment within crystal domains of a ferromagnetic particle.

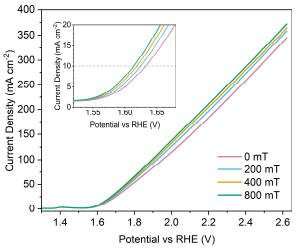
Unpaired electrons in the catalyst align with the external magnetic field. Spin-polarisation can:

- improve intra-particle charge transport via spin channels
- directly enhance oxygen evolution by favouring paramagnetic $^3O_2$ formation

Results & Discussion

Using an electrocatalytic water-splitting system in a direct-field electromagnet, magnetic field effects are being studied by varying: ✓ magnetic properties of catalysts, ✓ electric current in the system and ✓ magnitude of magnetic field.

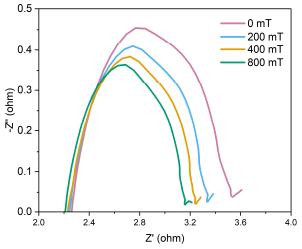




Nickel foam catalyst

Linear Sweep Voltammetry:

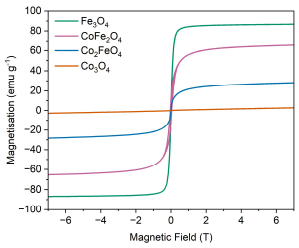
- Electrode reaches higher current densities with increasing magnetic field
- Overpotential (10 mA cm^{-2}) decreased by 20 mV between 0 and 800 mT



Nickel foam catalyst

Impedance Spectroscopy at 1.8 V:

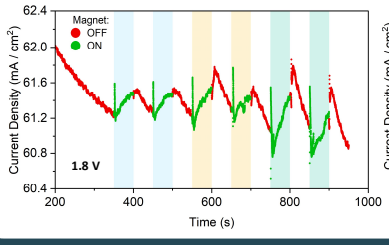
- Resistance of solution and of charge transfer at electrode surface decreases from 0 → 800 mT
- Lowered resistance may lead to positive magnetic effects on system performance

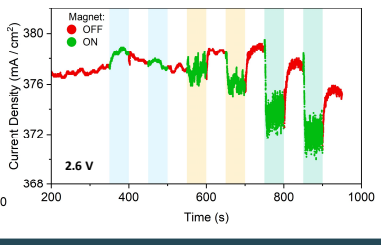


Co-Fe oxide catalyst series

SQUID magnetometry:

- Paramagnet to strong ferromagnet
- Magnetic properties controlled *via* Co : Fe ratio.





Nickel foam catalyst

Chronoamperometry with increasing magnetic field pulses at 200 mT, 400 mT and 800 mT:

- At 1.8 V, positive magnetic effects are observed which increase as the field strengthens
- At 2.6 V, a positive effect is seen at 200 mT which turns negative at higher fields.
- The susceptibility of higher current densities to negative effects may result from diverted current movement in the electrode resulting from Lorentz force.

References:
Y. Li, Z. Wang, Y. Wang, A. Kovács, C. Foo, R. E. Dunin-Borkowski, Y. Lu, R. A. Taylor, C. Wu and S. C. E. Tsang, *Energy Environ. Sci.*, 2022, **15**, 265–277
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