Efficient Bifunctional Nickel-Iron Hydroxides Electrocatalyst for Green Hydrogen Production

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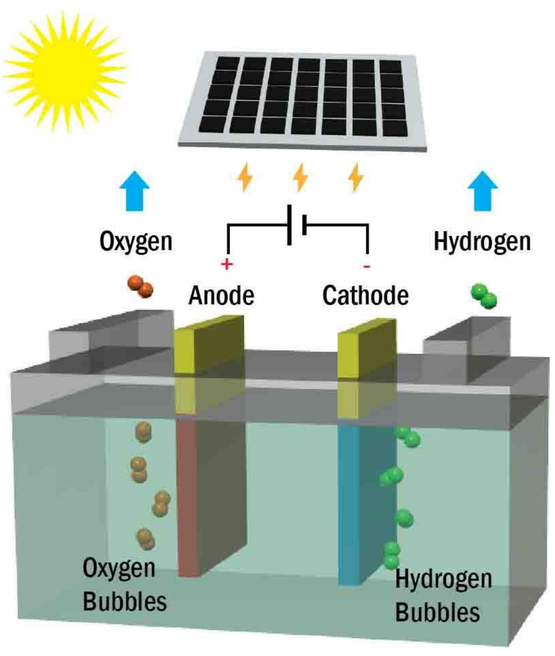
1. Water electrolysis to green hydrogen for future energy supply

The production of green hydrogen *via* alkaline water electrolysis powered by the solar-generated renewable electricity offers an efficient means to locally convert the intermittent solar energy to clean chemical fuels.[1,2]



❖ **Solar-powered Water electrolysis**

In alkaline solutions:

- Anode (oxygen evolution reaction, OER):
- $4OH^- \rightarrow H_2O + O_2 + 4e^-$
- Cathode (hydrogen evolution reaction, HER):
- $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

Total reaction: $2H_2O \rightarrow 2H_2 + O_2$

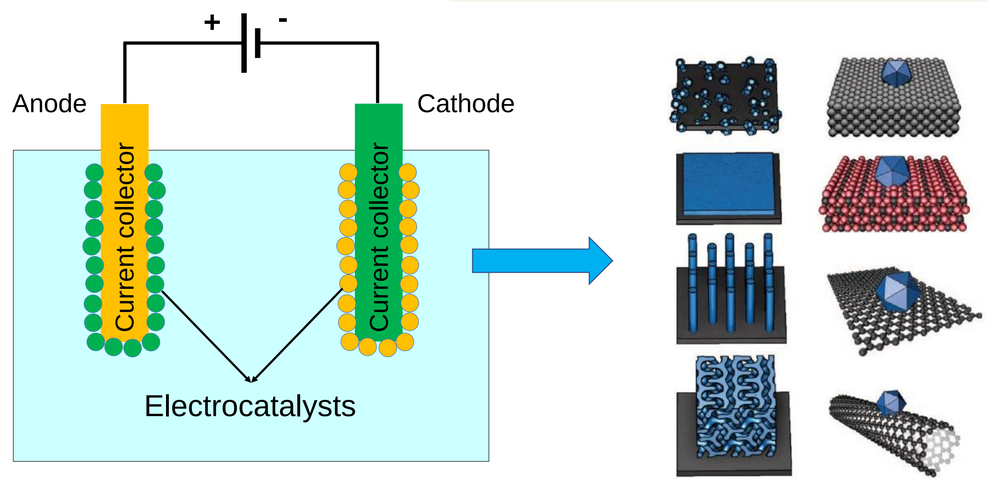
Water (H_2O) breaks into oxygen (O_2) and hydrogen (H_2).

2. Electrodes play an important role in water electrolysis

❖ A high performance alkali electrolyser requires highly active and stable anode and cathode.

Electrocatalyst development strategies:

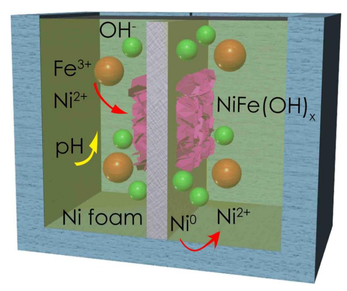
- ➢ Increasing the number of active sites;
- ➢ Increasing the intrinsic activity of each active site.[3]

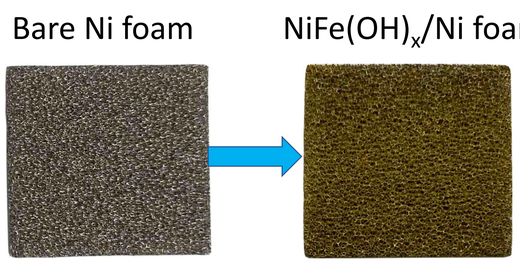


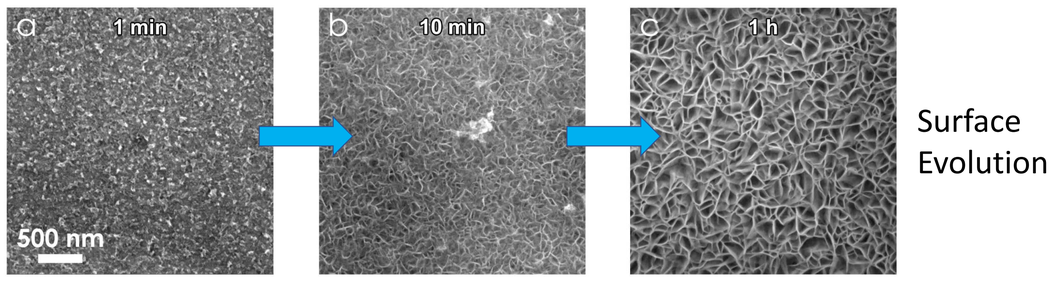
❖ **Low-cost, efficient and robust electrode system**

3. Low-cost, energy-efficient and green synthesis strategy

Nickel-iron hydroxides ($NiFe(OH)_x$) nanosheets were in-situ grown on Ni foam via a simple immersion method at room temperature.



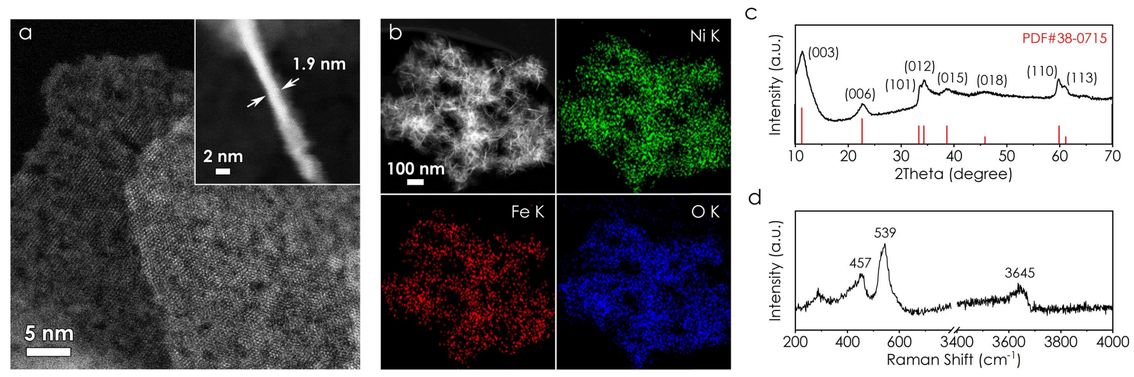




Surface Evolution

4. Defect-rich and ultrathin nature of $NiFe(OH)_x$ nanosheets

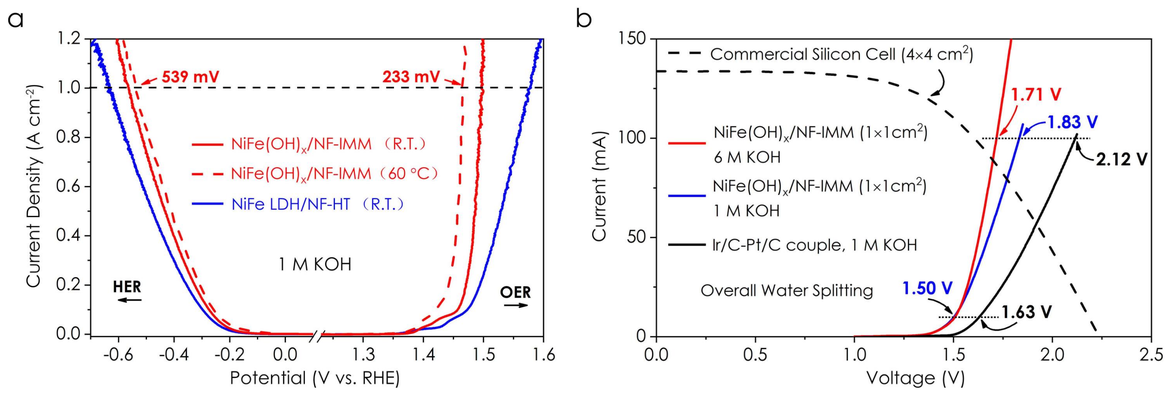
HRTEM, STEM, XRD and Raman analysis were conducted to characterize the structural properties of $NiFe(OH)_x$ electrocatalysts.



- ➢ HRTEM: the thickness of one nanosheet was observed to be ca. 1.9 nm;
- ➢ STEM EDX elemental mapping: Fe, Ni and O elements are homogeneously distributed over the $NiFe(OH)_x$/NF nanosheets;
- ➢ XRD: the peaks were attributed to the characteristic peaks of α-phase $Ni(OH)_2$;
- ➢ Raman: the symmetric Ni-OH stretching mode (457 cm^{-1}) and the vibrations of the Ni-O stretching mode with structural defects or crystalline disordering (539 cm^{-1}).

5. High-performance bifunctional catalysts for water splitting

❖ **Solar energy-powered overall water splitting**



- ➢ The two-electrode overall water splitting device can achieve the current density of 10 mA cm^{-2} at the voltage of 1.50 V in 1 M KOH (and 100 mA cm^{-2} at 1.71 V in 6 M KOH).
- ➢ The water electrolysis device can be powered by a commercial Si solar cell, and the operating current is about 80 mA with excellent stability.

6. Conclusions

- ➢ Green hydrogen production was achieved by a solar-powered water electrolysis system;
- ➢ A room-temperature one-step immersion strategy was adopted to synthesize efficient NiFe hydroxides electrocatalyst on Ni foam;
- ➢ Ex-situ and in-situ characterization demonstrated the defect-rich, ultrathin nature of $NiFe(OH)_x$ nanosheets;
- ➢ The obtained $NiFe(OH)_x$ electrode exhibited outstanding performance towards overall water splitting;
- ➢ A two-electrode water electrolysis device can achieve a current density of 10 mA cm^{-2} at the voltage of 1.50 V in 1 M KOH and can be powered by a cheap commercial silicon solar cell.

References

1. John A. Turner, Science, 2004, 305, 972-974.

2. J. Luo et al., Science, 2014, 345, 1593-1596.

3. Z. W. She et al., Science, 2017, 355, DOI: 10.1126/science.aad4998.

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