Engineering a Bifunctional Metal–Organic Framework for Efficient and Cost-Effective Hydrogen Production and Storage

Abdullah Alghamdi. Alhussan Private School, Dammam, Saudi Arabia.

EGSD018

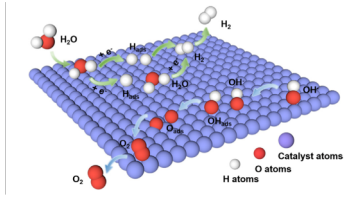
Research Question and Aim

Broader Context:

- Green hydrogen, produced from water, is a promising clean energy-rich fuel that enables a sustainable, affordable, and secure global energy system.

Specific Problem:

- Currently used materials to split water and produce H_2 have limitations such as corrosion, high cost, and dissolution.
- High pressure and low temperature are needed in conventional hydrogen storage, posing safety concerns and requiring complicated infrastructure.



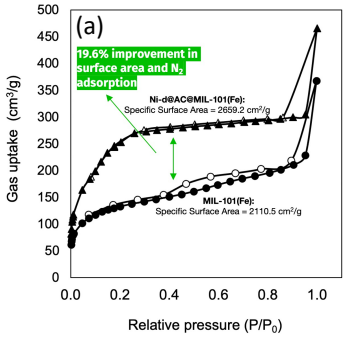
Scheme 1. Illustration of the reaction pathway for HER (green arrows) and OER (blue arrows) in alkaline media [1]

- **Aim:** to synthesize and engineer a novel, cost-effective, and efficient metal–organic framework (MOF) to produce green H_2 from water and store it at relative minimal pressure and temperatures.

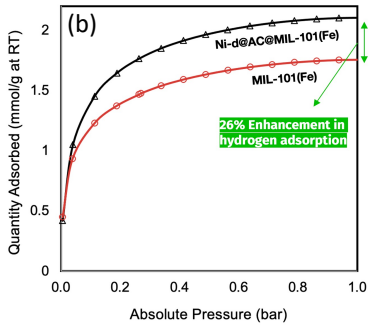
[1] Min Yang at Applied Materials Today. 2020.

Data Analysis & Results

Surface Area



Hydrogen Storage



Water-splitting

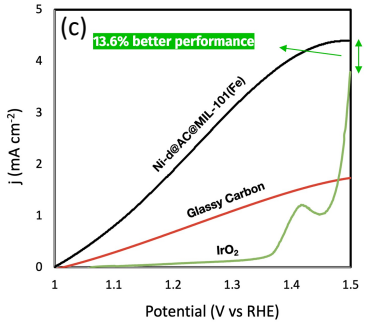


Figure 1. (a) Nitrogen adsorption–desorption BET isotherm of MIL-101(Fe) and Ni-d@AC@MIL-101(Fe). Filled (adsorption) and empty (desorption) symbol, **(b)** Adsorption isotherms of hydrogen on the MIL-101(Fe) and Ni-d@AC@MIL-101(Fe), and **(c)** Linear sweep voltammetry (LSV) of the Ni-d@AC@MIL-101(Fe), glassy carbon, and IrO_2 (RHE).

Procedures

Synthesis

- Built on the solvothermal synthesis of the MIL-101(Fe) MOF; yet added activated carbon (AC) in-situ and doped nickel post-synthetically (**21 trials**).
- Washed the material several times, then dried it at room temperature.

Characterization

- Characterized the material using a scanning electron microscope (SEM), transmission electron microscope (TEM), and x-ray diffractometry (XRD).

Performance Evaluation

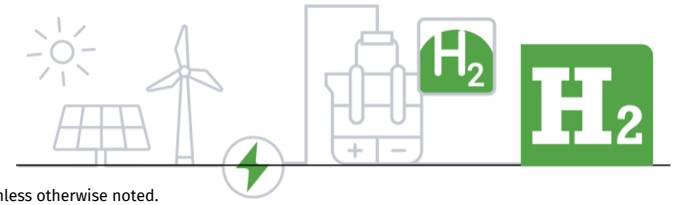
- Measured the water-splitting performance and stability using linear sweep voltammetry (LSV) and chronoamperometry tests in a three-electrode system.
- Evaluated the gas adsorption properties with BET analysis and hydrogen isotherm.

Conclusion

This novel metal–organic framework:

1. Enhanced the water-splitting and hydrogen production after the modification, which proved to be 13.6% better than the benchmark, IrO_2 at 1.5 V.
2. Built and engineered the MIL-101(Fe) without the collapse of the framework, which improved the surface area by 19.6% and the hydrogen uptake by 26% at 1 bar.
3. Could store hydrogen in off-grid systems (houses, research facilities, etc.) at relative minimal pressure and temperatures, and produce H_2 at a fraction of IrO_2 cost and higher efficiency.

This work has the potential to help decarbonize the transportation and power sectors once deployed.



All figures, photos, and diagrams were created by the student research, unless otherwise noted.