Electromagnetic field-assisted thermal catalysis enabling low-temperature, low-pressure, large-scale ammonia synthesis

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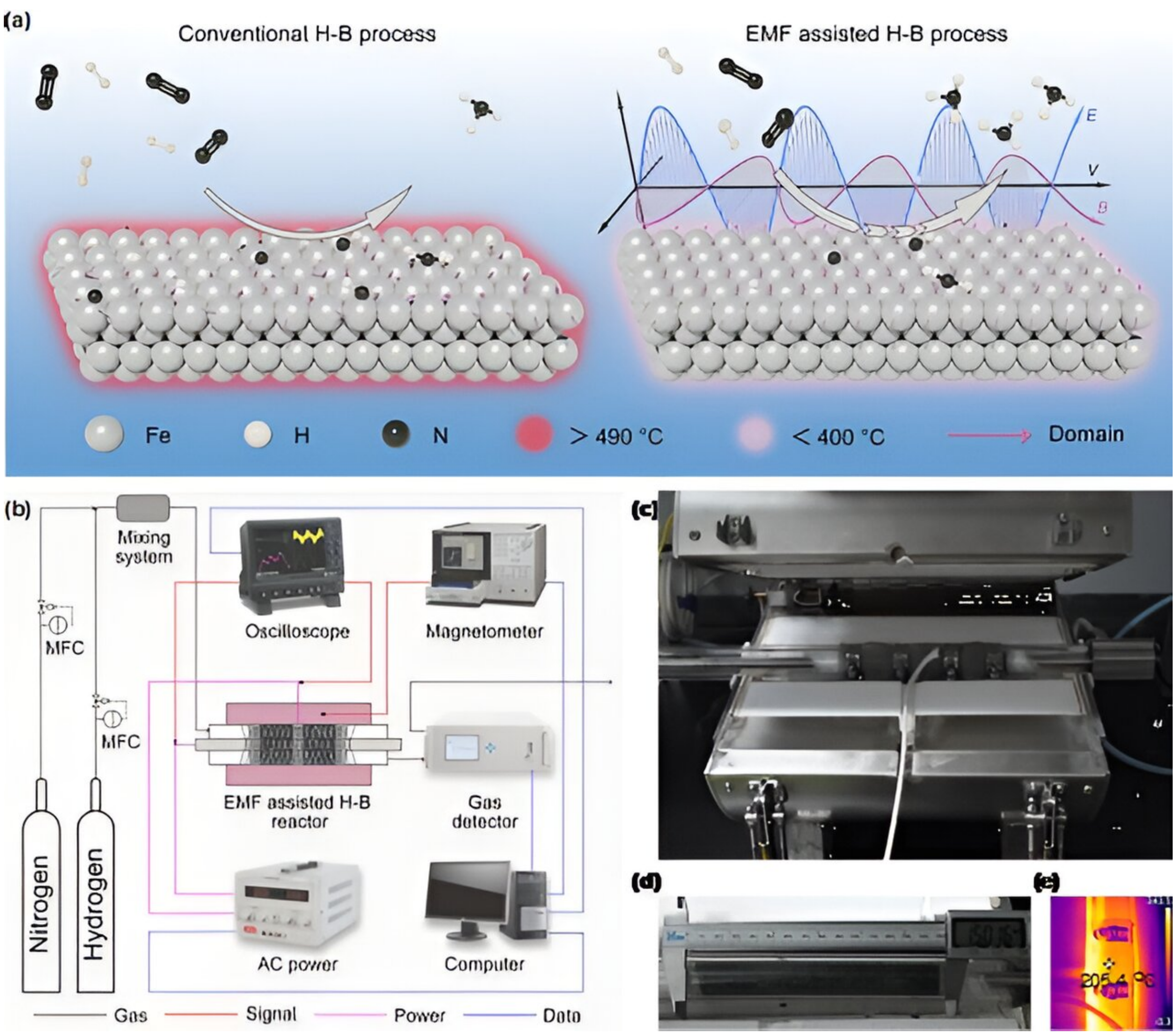
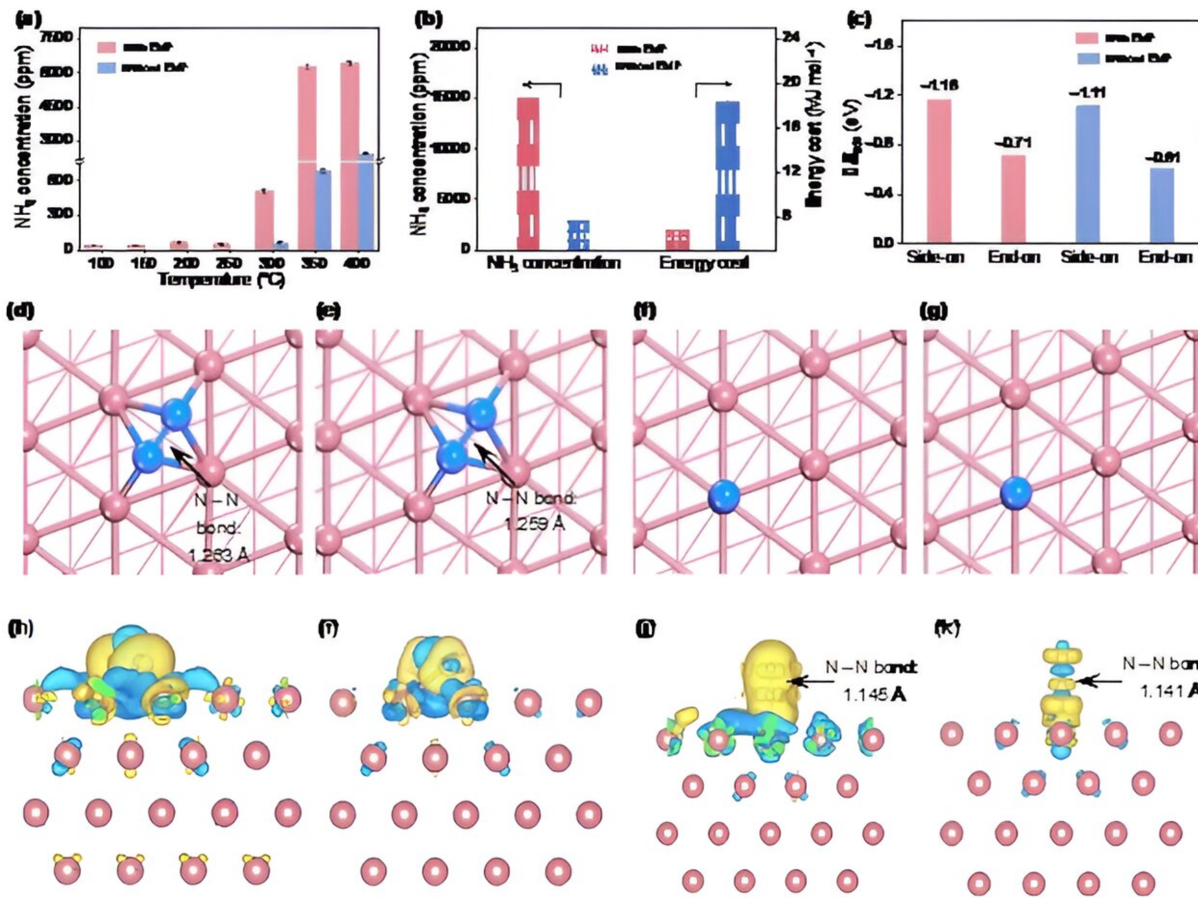


(a) Working principle for conventional and EMF-assisted H-B strategies. (b) The technological flow diagram of EMF-assisted ammonia synthesis. (c) Digital photograph of the EMF reactor. (d) Digital photograph of a quartz tube filled with 80 g Fe-based catalyst for the scale-up experiment. (e) Infrared thermal imaging of the reaction zone with external heating of 200 ℃. Credit: Science China Press

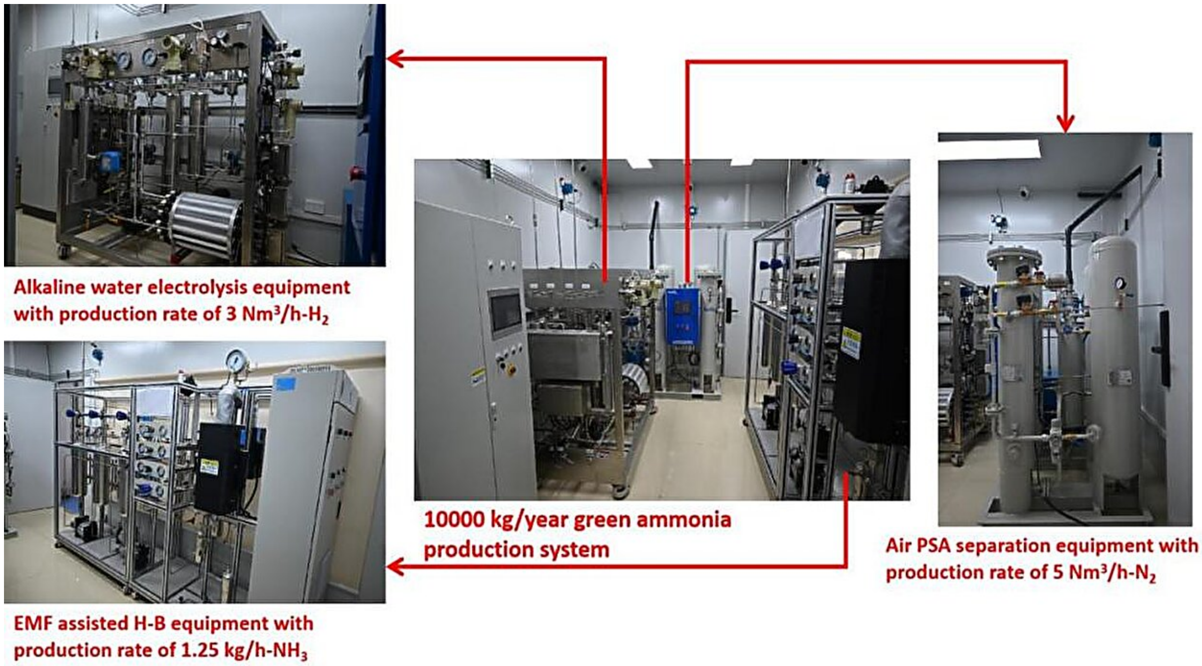
Ammonia (NH_3), as one of the most common industrial chemicals, is essential for nitrogenous fertilizer production and shows potential as a next-generation green fuel. Industrial ammonia synthesis relies on the reaction of fossil fuel-derived hydrogen and nitrogen (Haber-Bosch method) under high temperature (~500 °C) and high pressure (>15 MPa), which consumes ~2% of global power and discharges ~1.5% of global greenhouse gas.

A team from Tianjin University in China developed an electromagnetic field (EMF)-assisted H-B technique for ammonia synthesis under mild conditions by adopting commercial iron-based catalysts. The onset temperature with EMF assistance is 100 °C, which is obviously lower than that without EMF assistance (300 °C).

In a typical scale-up experiment with 80 g commercial catalysts, the EMF-assisted H-B technique obviously increases the ammonia yield (~5 times) and decreases the energy consumption (~2.7 times). The enhanced catalytic performance can be ascribed to the EMF inducing more electron transfer from Fe orbitals to N≡N orbitals in both side-on and end-on adsorption modes.



(a) Ammonia concentration under different temperatures with and without an EMF at 1 MPa. (b) Comparison of ammonia concentration and energy cost for the scale-up experiment at 200 ℃ and 1 MPa with and without the EMF. (c) Adsorption energy of N2 on Fe(110) with and without an EMF (1 V Å-1). Atomic structure of N2 side-on adsorption on the Fe(110) surface with (d) and without (e) an external electric field and N2 end-on adsorption on the Fe(110) surface with (f) and without (g) an external electric field. Gray ball: Fe, blue ball: N. Charge density difference of N2 side-on adsorption with (h)and without (i) an external electric field and N2 end-on adsorption with (j) and without (k) an external electric field. The isosurface value is 0.003 e Å-1The yellow isosurface represents electron accumulation, and cyan denotes electron depletion. Credit: ©Science China Press



A pilot-scale system includes alkaline water electrolysis equipment, air PSA separation equipment and EMF-assisted H-B equipment. Credit: Science China Press

They constructed a pilot-scale system with a production capacity of 10,000 kg per year for EMF-assisted thermal catalysis at Tianjin University, taking the first step in the development of EMF-assisted thermal catalysis for industrialization from the laboratory.

They are carrying out further scale-up research on EMF-assisted thermal catalysis in Qinghai Province, which is rich in renewable energy, to explore a feasible industrial path for the breakthrough of large-scale storage and transportation bottlenecks of renewable energy to promote the early realization of the "dual carbon" goal.

The research is published in the journal *Science Bulletin*.

More information: Bao Shun Zhang et al, Electromagnetic field-assisted low-temperature ammonia synthesis, *Science Bulletin* (2023).
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