(1) Electrochemical Nitrogen Reduction to Ammonia with Carbon-Metal Electrocatalysts

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Ammonia, a key fertilizer and clean fuel, is mainly produced via the energy-intensive Haber-Bosch process, consuming nearly 2% of global energy and generating significant greenhouse gases. This talk focuses on electrochemical nitrogen reduction to ammonia using carbon-metal electrocatalysts as a sustainable alternative. We developed an inexpensive, scalable method to synthesize metal single atoms and nanoparticles on mesoporous nitrogen-doped carbon as electrocatalysts. A gas diffusion electrode flow cell was built to test catalyst performance under continuous operation. Electrochemical characterization combined with machine learning revealed that activation polarization primarily limits performance, governed by intrinsic active-site kinetics and accessible surface area. Meanwhile, pore size, particle dispersion, and electrode wettability affect site accessibility rather than mass transport. This study offers a unified framework linking catalyst structure, electrode design, and kinetic limitations in electrochemical nitrogen reduction flow cells, advancing efficient ammonia production technologies.

(2) Tuning Photo(electro)Catalytic Performance through Plasmon-Enhanced Binary and Ternary Architectures

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Metal-oxide semiconductor photoelectrodes are widely studied for energy and environmental applications, yet their performance is limited by poor light harvesting, rapid charge recombination, and sluggish surface kinetics. Here, we highlight an emerging strategy that integrates metal–organic frameworks (MOFs), semiconducting oxides, and plasmonic nanostructures to construct binary and ternary photoelectrode systems.
By tuning key parameters, these hybrid architectures significantly enhance photo(electro)catalytic performance. Their potential is demonstrated in applications such as water splitting and hydrogen peroxide production. Challenges and future prospects for developing scalable, cost-effective, and sustainable plasmonic MOF/oxide-based systems are also discussed.