CO_2 and H_2 technologies for clean energy transition

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The 2019 International Energy Agency report states that 80% of global energy comes from chemical fuels, with 67% from fossil fuels, while electricity only accounts for 20%. This reliance on fossil fuels leads to energy shortages, significant CO_2 emissions, and limited use of cleaner electricity. Transitioning to renewables is crucial for sustainability, where CO_2 and H_2 technologies play vital roles.

To mitigate the excessive CO_2 emissions from burning fossil fuels, various strategies, including CO_2 capture and storage technologies, have been implemented. A desirable next step is to convert this captured CO_2 into value-added chemicals and renewable fuels, reducing fossil fuel dependency and advancing the Circular Economy. Among the conversion methods, electrochemical CO_2 conversion powered by renewable electricity stands out as particularly promising, as it also increases the integration of electricity into the energy mix. However, despite its appealing nature, this technology faces significant challenges due to CO_2's low energy content, high reaction energy barriers, slow electroreduction kinetics, and low selectivity for specific products. To address these challenges, the development of highly active, selective and stable catalysts, along with optimized electrolysis processes, is crucial.

Our work is dedicated to advancing both catalyst development and the refinement of the electrolysis process for effective CO_2 reduction.

Hydrogen technology, with its numerous advancements, is emerging as one of the most promising options in the transition to sustainable energy. Innovative hydrogen technologies, including production, storage, distribution, and usage, are increasingly being integrated across various industries. Currently, hydrogen use is most notably associated with polymer electrolyte membrane fuel cells (PEMFCs), which have gained significant attention for both automotive and stationary applications, aligning with the zero-emission goals of future economies and infrastructure. However, a key challenge of PEMFC development is the sluggish oxygen reduction reaction (ORR) at the cathode, which necessitates high levels of platinum group metals (PGMs). To make automotive applications economically viable, one strategy is to reduce platinum loadings on the cathode to below 0.1 mg_{Pt}/cm^2 while maintaining fuel cell performance. Another approach involves replacing noble metal catalysts with non-precious materials.

Our research is focused on developing advanced catalysts for ORR and their application in fuel cells, aiming to overcome these challenges and drive hydrogen technology forward.