

# CO<sub>2</sub> hydrogenation to fuel and chemicals

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In recent years, tremendous efforts have been put on CO<sub>2</sub> utilization trying to convert them back to chemical products or energy. However, the amount of energy required to convert CO<sub>2</sub> into an energy product is certainly higher than that can be provided by the resulted energy product. Hence, CO<sub>2</sub> can be regarded as a carbon energy resource only if renewable energy is available and incorporated into the energy products. In this case, CO<sub>2</sub> can be regarded as a carbon resource to provide compositional carbon element for new chemical molecules. As a result, CO<sub>2</sub> can be regarded as an energy carrier for the transformation of renewable energy.

In chemistry, CO<sub>2</sub> utilization plays a role to complete the redox cycle, which is intrinsically redox reactions in nature. Charge transfer is the key step for the occurrence of the reactions. Moreover, the selective control becomes the key issue for CO<sub>2</sub> hydrogenation into fuels or chemicals. For the purposes, nano/sub-nano catalysis plays a key role in CO<sub>2</sub> activation and conversion in the presence of hydrogen, which involves single atom and single site catalysis, nano domain at different size and nano composite catalytic materials, nano scale such as distance, distribution, coverage and even mesoscale understandings for nano catalysis, and their surrounding, i.e. chemical environment and geometric environment for active sites.

For CO<sub>2</sub> hydrogenation to methanol, we designed the confined Cu-based catalysts *via* hydrotalcite-like precursors with high activity and stability and finished the sigle-tube pilot-scale test. Nano particle size and surrounding are both important. It was found that CO<sub>2</sub> conversion was related to the dispersion of Cu and the CH<sub>3</sub>OH selectivity was related to the distribution of basic sites on catalyst surface. Recently, we discovered that the integration of reducible In-based oxides, which is responsible for the activation of CO<sub>2</sub> and H<sub>2</sub>, and zeolites responsible for the selective C–C coupling, can realize the direct synthesis of gasoline fuels and lower olefins from CO<sub>2</sub> hydrogenation with excellent selectivity. The selectivity to gasoline-range hydrocarbons (C<sub>5</sub>–C<sub>11</sub>) can reach 78.6% with only 1% of CH<sub>4</sub>, and C<sub>2</sub>–C<sub>4</sub> olefins selectivity reached up to 80%. The proximity of these two components plays a crucial role in giving high selectivity to gasoline and olefin. Moreover, the pellet catalyst exhibits much better performance during industry-relevant test, suggesting a promising prospect for industrial applications.