Plasma Catalysis for CO_2 Hydrogenation to Methanol

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Catalytic CO_2 hydrogenation to green methanol is a promising CO_2 conversion route for reducing emissions while producing valuable fuels and chemicals. Methanol can serve as a transportation fuel, a feedstock for other chemicals, and a hydrogen storage medium. However, conventional thermal catalysis for CO_2 hydrogenation to methanol typically requires high pressures and relatively high temperatures, resulting in low single-pass CO_2 conversion and low methanol yield due to the inert nature of CO_2. Developing emerging and sustainable processes for CO_2 hydrogenation to methanol under more benign conditions has therefore attracted increasing interest, particularly for decentralized green methanol production using renewable energy.

We have developed an innovative plasma-catalytic process for CO_2 hydrogenation to methanol, achieving an impressive single-pass CO_2 conversion of over 50% and a methanol yield exceeding 27% at room temperature and ambient pressure. This process offers the unique advantage of instant on/off capability, providing great flexibility for grid-free, decentralized production of liquid fuels using intermittent renewable energy. Our techno-economic analysis indicates that compared to conventional thermal catalysis, this technology reduces capital costs by 52% and lowers green methanol production costs by 10% and 36% when electricity prices are 60 €/MWh and 20 €/MWh, respectively. By enabling cost-effective and decentralized green methanol production under mild conditions, this technology not only supports a circular carbon economy but also promotes energy independence and resilience in regions with abundant intermittent renewable energy resources.