Hydrogenation of CO_2 into formic acid with bio-hybrid catalysts

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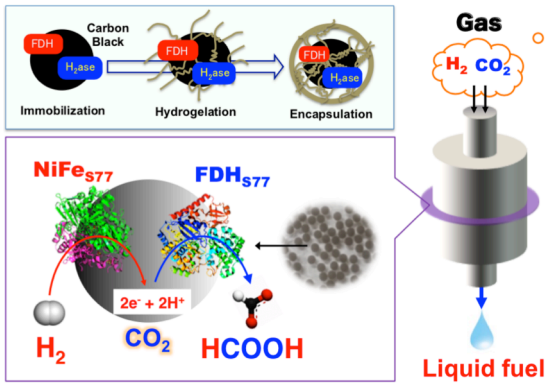
Catalytic reduction of CO_2 to formic acid by using H_2 has received increasing attention because of the growing importance of carbon abatement technologies, hydrogen energy carriers, and carbon-neutral chemical feedstocks. To date, various types of homogeneous and heterogeneous catalysts, including Ru or Ir complexes, Pd or Au nanoparticles, and supported Pd catalysts, have been synthesized to develop efficient systems for catalytic production of formic acid from CO_2 and H_2. However, these synthetic catalysts systems still require expensive noble metals as active sites, high-pressure source gases, and high reaction temperatures. On the other hand, utilizing biocatalysts enabled solving these problems and producing formic acid under mild conditions. Therefore, we have isolated and characterized O_2-stable membrane-bound [NiFe]-hydrogenases and [Mo]-formate dehydrogenases from our isolated bacteria (References). Inspired by these biocatalysts having unique O_2-stablility and their catalytic behaviors, we have constructed bio-hybrid catalysts by immobilizing the two membrane-bound enzymes on carbon black and then encapsulating them in gellan gum. The bio-hybrid system efficiently catalyzed the hydrogenation of CO_2 to yield only formate under very mild conditions of H_2 and CO_2 (v/v = 1:1, 0.1 or 1.0 MPa) at 303 K. Importantly, the system also functioned as a heterogeneous catalyst to efficiently produce formate from CO_2 and H_2 even in the presence of O_2, unlike other biocatalysts.



Biocatalytic CO_2 hydrogenation into formate

References

Nature 2011, 479, 253-256; *J. Biosci. Bioeng.* 2012, 114, 479-484; *J. Biosci. Bioeng.* 2014, 118, 386–391; *Angew. Chem. Int. Ed.* 2014, 53, 8895–8898; *Science* 2017, 537, 928–932; *Chem. Commun.* 2018, 54, 12385–12388.