

Nanoporous materials for electrochemical systems

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Due to rising energy demand and evidence of the environmental effects of CO₂ emissions, much research has focused on producing and storing energy from renewable sources. An efficient and selective process for the conversion of CO₂ to CO or other reduced products could allow a widespread production of liquid fuels, because CO has been used as feedstock in the Fischer-Tropsch process to produce chemicals and synthetic fuels for many decades. Coupled with renewable electricity sources, it could help solve the large scale storage issue of renewable energies while creating a carbon neutral energy source easily integrated into the current energy infrastructure. An effective CO₂ reduction catalyst is the key component of CO₂ electrolysis systems.

Recently, we discovered that nanoporous silver can reduce CO₂ electrochemically to CO in a highly efficient and selective way. The highly porous structure creates an extremely large surface area for catalytic reaction, and the curved internal surface generates a large number of highly active step sites for CO₂ conversion, resulting in an exceptional activity that is over three orders of magnitude higher than that of the polycrystalline counterpart at a moderate overpotential of < 500 mV. More importantly, such a remarkable activity for CO₂ electroreduction has been achieved with a CO Faradaic efficiency of 92%.

We also extended our efforts to non-precious metal based hydrogen evolution (HER) catalyst, a hierarchical nanoporous copper-titanium (np-CuTi) bimetallic electrocatalyst, which is able to produce hydrogen from water under a mild overpotential at a rate more than two times higher than that of the current state-of-the-art carbon-supported Pt catalyst. Although both Cu and Ti are known to be poor HER catalysts, the combination of these two elements creates unique Cu-Cu-Ti hollow sites, which have a hydrogen binding energy very similar to that of Pt, resulting in an exceptional HER activity. Additionally, the hierarchical porosity of the np-CuTi catalyst also contributed to its high HER activity, because it not only provides a large surface area for electrocatalytic HER, but also improves the mass transport properties. Moreover, the np-CuTi catalyst is self-supported, eliminating the overpotential associated with the catalyst/support interface.