

Designing Highly Efficient Solid Oxide Electrodes for Co-electrolysis of CO₂-H₂O

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Due to the ever-increasing energy demand from fossil fuels in the past several decades, the traditional carbon-based power generation, accompanied with a large amount of effluent greenhouse gas emission (mainly CO₂), is considered to be the main cause of global warming and severe environmental impact. Finding efficient approaches for the utilisation and management of effluent emission of CO₂ is highly important subjects. Electrochemical energy storage devices, converting electric energy into the form of chemical fuels for storage, are expected to be promising for the future energy applications. Solid oxide electrolysis cells (SOECs) are critical examples and have been reported as highly efficient energy storage devices using renewable energy to produce useful fuels. Particularly, the devices enable effectively mitigating the increase of CO₂ in the atmosphere while converting CO₂/H₂O into CO/H₂ syngas, and even directly producing liquid fuel and hydrocarbon feedstocks through co-electrolysis of CO₂-H₂O. In order for SOECs to be applied commercially, the activity, conversion efficiency and stability of the fuel electrode must be significantly improved.

This presentation will briefly introduce the current development and highlight the critical issues (such as insufficient electrochemical activity, irreversibility, long-term stability in operation and the effect of water gas shift reaction) in CO₂/H₂O co-electrolysis. To address these critical issues, several types of potential materials, such as Ni-based cermet, LaFeO₃-based perovskite oxide and spinel oxide, will be examined as fuel electrodes applied in the co-electrolysis. To date, Ni-based cermet materials have most commonly been used as the fuel electrode for SOECs, while constant circulation of reducing gas (i.e. H₂) is required in order to prevent the reoxidation of the metallic phase, which can lead to an issue of long-term operation. Recently, perovskite oxides have been suggested to use as fuel electrodes instead of metal-based cermet electrodes because of their relatively good stability and compatibility. A notable finding was that LaFeO₃-based perovskite uniquely enables an excellent control of syngas ratios and can significantly suppress water gas shift reaction (WGSR, $\text{CO} + \text{H}_2\text{O} \leftrightarrow \text{CO}_2 + \text{H}_2$), although its electrolysis current density is still insufficient. To further increase in activity and electrolysis current density, more recently, we have developed a novel type of material having self-exsolved metal-based cermet nanoparticles decorated on CuFe₂O₄ spinel oxide surfaces as highly active sites for enhancement of electrochemical performance in co-electrolysis. Moreover, it was found that mixing CuFe₂O₄ and LaFeO₃-based perovskite was effective for remarkable improvement of the cell performance in co-electrolysis. These potential fuel electrodes show excellent Coulombic (Faradaic) efficiency of CO+H₂, over 95% achieved for the application of CO₂/H₂O electrolyser.

