Novel Cu-exsolved $CuFe_2O_4$ Cathode Towards Enhancement of Electrochemical Performance in CO_2/H_2O Electrolysis

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An increasing awareness of severe environmental impact has been seriously concerned. An important indication is from global warming effect, caused by effluent greenhouse gas emission (mainly CO_2). Finding efficient approaches for the utilisation and management of effluent emission of CO_2 is highly important subjects. Solid oxide electrolysis cells (SOECs) driven by renewable energy is a promising approach to effectively mitigating the increase of CO_2 in the atmosphere while converting CO_2 into useful fuels for energy storage (e.g. H_2/CO "syngas" mixtures and hydrocarbon feedstocks).

To date, Ni-based cermet materials have most commonly been used as fuel electrodes for SOECs, while constant circulation of reducing gas (i.e. H_2) is required in order to prevent the reoxidation of the metallic phase, which can lead to an issue of long-term operation. Hence, a suitable fuel electrode with high activity and low degradation rate is essential for the application of high-temperature electrolyser. More 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. However, its insufficient current density and catalytic activity limits the operation in a low- and intermediate temperature. For example, in previous study of La(Sr)Fe(Mn)O_3 cathode, an average current density of 0.65 A/cm^2 was achieved at 1.6 V and 800°C.[1] In addition, significant A-site segregation (SrO) is generally formed on the surface at an elevated temperature, likely leading to certain chemical reactions (e.g. $SrCO_3$ formation) and resulting in the degradation of the electrolysis performance. Thus we recently proposed to use spinel oxides, a general formula AB_2O_4, which are composed of two transition metals and is an alkline earth metal free oxide.[2] Spinel oxides have been used in various catalytic applications. This type of material is expected to provide a higher current density of electrolysis and possess a mixed termination of transition metals as active roles to facilitate the reduction of CO_2 and H_2O.

This talk will briefly introduce the current development and critical issues in SOECs, and investigate spinel oxides as cathodes applied in the CO_2/H_2O co-electrolysis using LSGM as the electrolyte. We have found that one of spinel oxide, $CuFe_2O_4$, can perform superior current density values of 1.8 A/cm^2 achieved in CO_2/H_2O co-electrolysis at 1.6 V and 800°C.[3] This material shows excellent Coulombic (Faradaic) of CO+H_2, over 95% achieved. Also, exsolution of metallic Cu nanoparticles are observed after CO_2/H_2O co-electrolysis. It is considered that the superior electrochemical activity to CO_2/H_2O electrolysis is boosted by the active Cu-exsolved nanoparticles on $CuFe_2O_4$. Therefore, this novel material is expected to be a potential cathode candidate for the application of CO_2/H_2O electrolyser.

1. T. Ishihara, S. Wang and K.-T. Wu, *Solid State Ionics*, **299**, 60-63, (2017).
2. K.-T. Wu, T. Ishihara, *Solid State Ionics*, **329**, 46-51, (2019).
3. K.-T. Wu, J. Matsuda, A. Takagaki and T. Ishihara, *ECS Trans.*, **91**, 2425 (2019).