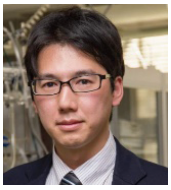
Energy conversion, Carbon-neutral, Green transformation

Multiscale design of CO_2 electrolysis systems



Research Center for Solar Energy Chemistry, Graduate School of Science
Associate Professor Kazuhide Kamiya
Researchmap https://researchmap.jp/kamiya0908?lang=en

Abstract

We have successfully increased the partial current density for electrochemical CO_2 reduction reactions to multicarbon products (C_{2+}) over Cu nanoparticles on gas diffusion electrodes in neutral electrolytes to a record value of 1.7 A/cm^2. The faradaic efficiency for multicarbon products increased with the current density and reached 76% at a total current density of 1.6 A/cm^2. Optimizing the standard components and their assembly as the cathode elicits the high-turnover frequency of Cu catalysts, resulting in the record partial current density for C_{2+}.

Background & Results

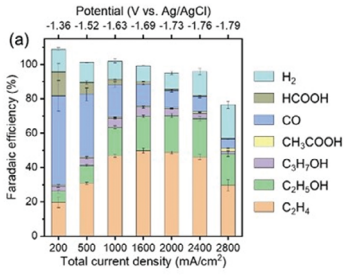
Electrochemical CO_2 reduction reaction (CO_2RR) has attracted considerable attention as a promising strategy for the valorization of anthropogenic CO_2. The increase in partial current density for synthesizing C_{2+}, such as ethylene and ethanol, is crucial for the social-implementation potential. Recently, the direct electroreduction of gaseous CO_2 using gas diffusion electrode (GDE) has been widely studied because it can overcome the problem of mass transport limitation due to the low solubility of CO_2. However, the partial current density for C_{2+} has remained below 800 mA/cm^2 even when using GDEs in most previous studies.

The present work attempts to pursue a high partial current density for C_{2+} (j_{C2+}) using neutral electrolytes by optimizing the standard components and properly assembling them as the cathode. In particular, we achieved a record current density of 1.7 A/cm^2 for multicarbon products in neutral electrolytes using synthetic or commercial Cu nanoparticles and carbon-based gas diffusion layers. The faradaic efficiency for C_{2+} increased with increasing current density in the present ultra-high-rate CO_2 electrolysis system, and thus, a trade-on relationship between rate and selectivity was exhibited.

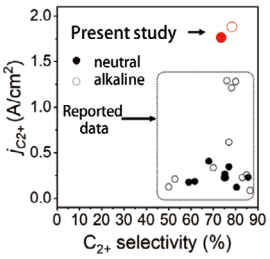
Although there are many requirements to obtain ultra-high-rate electrolysis, including the nature and size of catalysts, and the porosity of catalytic layers, we demonstrated that the thickness of catalyst layers was one high-sensitive factor in determining maximum current density for C_{2+}. We believe that this study suggests a novel approach to enlarging the triple-phase interface for enhancing the performance of electrocatalysis processes involving gases.

Significance of the research and Future perspective

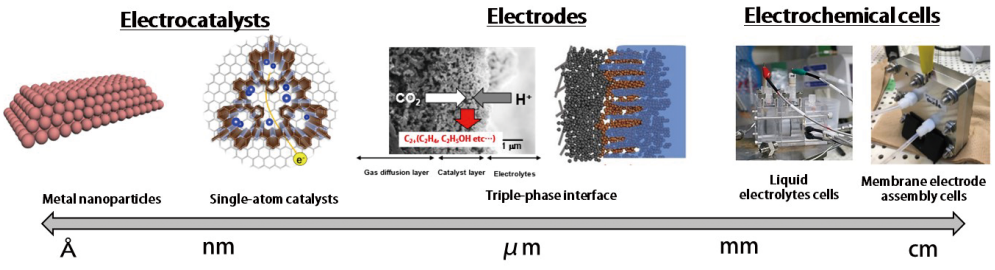
It is noteworthy that this electrode allowed us to achieve ultra-high-rate CO_2 electrolysis even in neutral solutions, which is more practical than alkaline solutions. In addition, the present study succeeded in eliciting the potential performance of an ordinary combination. The design guidelines obtained from the ultra-high-rate CO_2 electrolysis with only ordinary materials would be quite general, and thus, they are expected to be widely applicable to novel materials and systems.



Faradaic efficiencies of our CO_2 electrolysis



Comparisons with reported data



Multiscale design of CO_2 electrolysis systems

Patent
Treatise Inoue, Asato; Nakanishi, Shuji; Kamiya, Kazuhide et al. Ultra-high-rate CO_2 reduction reactions to multicarbon products with a current density of 1.7 A/cm^2 in neutral electrolytes. EES Catalysis. 2022 in press, doi: 10.1039/D2EY00035K
Liu, Tengyi; Nakanishi, Shuji; Kamiya, Kazuhide et al. A Tin Oxide-Coated Copper Foam Hybridized with a Gas Diffusion Electrode for Efficient CO_2 Reduction to Formate with a Current Density Exceeding 1 A cm^{-2}. Small. 2022 in press, doi: 10.1002/smll.202205323
URL https://rcsec.osaka-u.ac.jp/nakanishilab
Keyword chemical valorization of CO_2, electrocatalysts, multi-scale simulation, artificial photosynthesis