

Activity and Dissolution Stability of Ir/Ru- based Electrocatalysts Tested in a Model Proton Exchange Membrane Water Electrolyzer

Carolin Sophie Igel^{1,2*}, Maja Milosevic^{1,2}, Serhiy Cherevko¹

¹ Helmholtz-Institute Erlangen-Nürnberg for Renewable Energy (IEK-11), Forschungszentrum Jülich GmbH, Cauerstr. 1, 91058 Erlangen, Germany

² Department of Chemical and Biological Engineering, Friedrich-Alexander University Erlangen-Nürnberg, Cauerstr. 1, 91058 Erlangen, Germany

*c.igel@fz-juelich.de

The state-of-the-art proton exchange membrane water electrolyzers (PEMWE) rely on high iridium loading anodes providing the required device longevity at acceptable hydrogen production performance metrics. The current research efforts on developing more advanced devices are directed at deploying lower loading Ir oxide electrodes, decreasing Ir content in the catalyst, or substituting Ir with other more abundant materials. In this context, ruthenium (Ru) has been extensively studied using aqueous model systems (AMSs), e.g. rotating disk electrode (RDE) or scanning slow cell (SFC).^{1,2} However, the knowledge gained in idealized setups does not necessarily translate to real-world applications.

A metal-free-electrolyzer test station is used in the current work to quantify electrocatalyst dissolution during the electrolyzer operation.³ The setup allows parallel assessment of water splitting performance and Ir and Ru dissolution rates during the operation. A short testing protocol, similar to one used in our previous study for Ir,³ is chosen to quickly assess the relative stability of different electrocatalysts. As a model system designed to study the effect of Ru addition on the oxygen evolution reaction (OER) performance of Ir electrocatalyst, commercial samples with Ir:Ru ratios of 6:1, 3:1, and 1:1 are tested under identical conditions. All catalysts demonstrate overall stable behavior during the chosen protocol, with no significant activity changes observed. However, the quantification of Ir and Ru in the anode and cathode water lines and the cathode catalyst layer, revealed that while the overall performance was stable, the dissolution of both elements was substantial. Like in our previous experiments for pure Ir,³ the cathode catalyst layer is the primary sink for dissolved Ir and Ru from all the studied catalysts. The Ir:Ru 3:1 sample was found to be the most stable, followed by the 6:1 and 1:1 samples. Across all the analyzed compositions, Ru dissolution was significantly higher than that of Ir, which is in good agreement with the literature on AMSs.² Dissolved Ru was found in the water lines, as well as well as in the cathode catalyst layer (CCL). Additionally, it was found that the presence of Ru significantly promotes Ir dissolution and redeposition.

Further coupling of the cell to external analytics is on the way to further understand Ir and Ru dissolution mechanism at the relevant to actual application conditions. Such in-situ measurements will be complemented with a comprehensive port-mortem physicochemical characterization of the electrodes and membrane. The results will be compared and contrasted with those gained in the model SFC.² With this approach, we aim to improve our understanding of catalyst degradation and estimate if model systems can mimic the catalyst degradation behavior of real devices.

References

- [1] M. Carmo, D. L. Fritz, J. Mergel, and D. Stolten, *International Journal of Hydrogen Energy*, 2013, **38**, 4901–4934
- [2] S. Cherevko, S. Geiger, O. Kasian, N. Kulyk, J. Grote, A. Savan, B. R. Shrestha, S. Merzlikin, B. Breitbach, A. Ludwig and K. J.J. Mayrhofer, *Catalysis Today*, 2016, **262**, 170–180
- [3] M. Milosevic, T. Böhm, A. Körner, M. Bierling, L. Winkelmann, K. Ehelebe, A. Hutzler, M. Suermann, S. Thiele and S. Cherevko, *ACS Energy Letters*, 2023, **8**, 2682-2688