

Nanostructured iridium catalysts with high oxygen evolution performance for PEM water electrolysis

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Abstract

Proton exchange membrane water electrolysis (PEM-WE), compared to conventional alkaline water electrolysis (AWE), shows many advantages such as more compact configuration, higher energy efficiency, larger maximum current densities, higher H₂ purity, and dynamic flexibility of operation.[1] However, the rapid degradation of catalysts in the strongly acidic and highly oxidative environment severely limit the materials of choice. By far, iridium (Ir) based materials are the best performing electrocatalysts capable of catalyzing the oxygen evolution reaction (OER) in the acidic solution.[2] To enable widespread deployment of PEM-WE technology, the OER performance of Ir-based catalysts must be drastically improved and meanwhile the Ir utilization should be kept as minimal as possible.

In this presentation, our effort toward developing efficient and durable Ir-based nanocatalysts will be presented. We developed one-pot hydrothermal synthesis of ultrafine IrRu intermetallic nanoclusters loaded on conductive, acid-stable, amorphous tellurium nanoparticle support (IrRu@Te).[3] Benefiting from the large exposed electrocatalytically active surface of ultrafine IrRu clusters and the strong electronic coupling between IrRu and Te support, the as-obtained IrRu@Te catalysts show good catalytic performance for the OER in strong acidic electrolyte (i.e., 0.5 M H₂SO₄), requiring overpotentials of only 220 and 303 mV to deliver 10 and 100 mA cm⁻² and able to sustain continuous OER electrolysis up to 20 hours at 10 mA cm⁻² with minimal degradation. Moreover, IrRu@Te exhibits high specific activity, illustrating intrinsically better performance compared to that of unsupported IrRu and other commercial Ir and Ru based catalysts. It also demonstrates unprecedentedly high mass activity of 590 A g_{IrRu}⁻¹ at an overpotential of 270 mV, outperforming most Ir and Ru based OER catalysts reported in the literature. In addition, we managed to grow ultrafine oxygen-defective IrO_x nanoclusters on a high-surface-area, stable titanium substrate,[4] which showed low overpotentials of 277 and 336 mV to deliver 10 and 200 mA cm⁻² in 0.5 M H₂SO₄. Impressively, thus-prepared self-supported IrO_x nanoclusters exhibited superior mass activity of 1500 A g_{Ir}⁻¹ at an overpotential of 350 mV and can sustain constant OER electrolysis at a high current density of 200 mA cm⁻² for 130 hours with minimal degradation, showing great potential for use in practical PEM electrolyzers. Furthermore, our effort towards developing self-supported nanoporous ultrafine-grained IrO₂ (np-IrO₂) and nanoporous IrAl alloy electrodes (np-IrAl) will be presented.[5] We demonstrate that using np-IrO₂ as an anode and np-IrAl as a cathode, we can accomplish overall acidic water splitting at 10 mA cm⁻² with a low voltage of 1.52 V. Remarkably, the np-IrO₂ || np-IrAl electrode pair is able to split water stably in 0.5 M H₂SO₄ at a high current density of 100 mA cm⁻² up to 40 hours, showing substantial promise for use in PEM water electrolysis.

REFERENCES

- [1] F. M. Sapountzi, J. M. Gracia, C. J. Weststrate, H. O. A. Fredriksson, J. W. Niemantsverdriet *Prog. Energy Combust. Sci.*, 58 (2017) 1-35.
- [2] L. C. Seitz, C. F. Dickens, K. Nishio, Y. Hikita, J. Montoya, A. Doyle, C. Kirk, A. Vojvodic, H. Y. Hwang, J. K. Nørskov, T. F. Jaramillo *Science*, 353 (2016) 1011-1014.
- [3] J. Y. Xu, Z. Lian, B. Wei, Y. Li, O. Bondarchuk, N. Zhang, Z. P. Yu, A. Araujo, I. Amorim, Z. C. Wang, B. Li, L. Liu, *ACS Catal*, 10 (2020) 3571-3579.
- [4] Z.P. Yu, J. Y. Xu, Y. F. Li, B. Wei, N. Zhang, Y. Li, O. Bondarchuk, H. W. Miao, A. Araujo, Z. C. Wang, J. L. Faria, Y. Y. Liu, L. Liu, *J. Mater. Chem. A* in revision
- [5] Q. Li, J. J. Li, J. Y. Xu, N. Zhang, Y. P. Li, L. Liu, D. Pan, Z. C. Wang, F. L. Deepak, *ACS Appl. Energy Mater.* 3 (2020) 3736-3744.