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Novel manganese dioxide-based electrocatalyst formulations for bifunctional oxygen reduction and evolution reaction activity

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Development of highly active, durable and cost-efficient bifunctional electrocatalysts for the oxygen reduction and evolution reactions (ORR and OER) is of outmost importance for commercialization of rechargeable metal-air batteries (e.g., Zn-air, Al-air, Mg-air, Li-air) and regenerative H_2-O_2 fuel cells. Manganese dioxide (MnO_2), a low cost and abundant material, has been intensely studied as ORR electrocatalyst in alkaline media. Regarding the bifunctional ORR and OER electrocatalytic performance, however, enhancement of the activity (e.g., lower surface overpotential at practical current densities above 100 mA cm^{-2}) and improvement of the long-term stability are required for potential implementation in commercial systems. The purpose of this study is to present novel approaches for tuning the MnO_2 performance with co-catalyst addition, potassium ion doping and support effect (e.g., graphene and graphitized carbon). The combination of MnO_2 with structurally different oxide co-catalysts such as perovskite ($LaCoO_3$) or fluorite-type oxide (Nd_3IrO_7) produces a synergistic catalytic effect improving the bifunctional (ORR and OER) activity compared to the individual oxides. Doping of the oxide catalyst with potassium ions, either by long-term exposure to 6 M KOH or potential driven insertion (PDI), increases further the activity and durability as revealed in accelerated degradation experiments. Optimizing the MnO_2 electrodeposition conditions can produce nanostructured morphologies that are favorable for ORR and OER activity. The electrochemical studies are supported by extensive surface analysis (SEM, TEM, XPS, EDX, EELS). This work reveals new oxygen electrode catalyst formulations for rechargeable metal-air batteries and regenerative fuel cells.

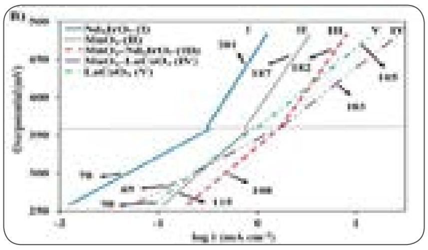

Figure 1: Tafel plots for the oxygen evolution reaction (OER) using diverse oxide electrocatalysts (6 M KOH) (293 K). The numbers indicate the calculated apparent Tafel slopes.

Recent Publications:

1. Hosseini Benhangi P, Alfantazi A and Gyenge E (2014) Electrochimica Acta 123:42-50.
2. Hosseini Benhangi P, Garcia Contreras M A, Alfantazi A and Gyenge E (2014) Journal of the Electrochemical Society 162: F1356-1366.
3. Hosseini Benhangi P, Kung C, Alfantazi A and Gyenge E (2017) ACS Applied Materials and Interfaces 9:26771-26785.

Biography

Elod L Gyenge is a Professor in the Department of Chemical and Biological Engineering and Clean Energy Research Centre at the University of British Columbia, Vancouver, Canada. His research is focused on electrocatalysis and electrochemical engineering for improving the performance of electrochemical power sources and electrosynthetic processes. His research led to many innovations for a variety of electrochemical systems including diverse fuel cells and rechargeable batteries, and electrosynthesis of hydrogen peroxide. The research materialized in over 75 refereed research publications in peer reviewed journals, over 40 invited presentations and 10 patents and patent applications. He has received a number of awards and recognitions, among them the Japanese Society for Promotion of Science (JSPS) Fellowship at Osaka University and Elisabeth and Leslie Gould Endowed Professorship at UBC (2007-2014). Since 2016 he is also cross-appointed Professor in the Graduate School of Engineering at Osaka University, Japan. He is a Co-Founder of two companies: Catalyst Square Materials Ltd. and Agora Energy Technologies Ltd

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