Efficient Water Oxidation Using Nickel-Hydroxide as an Electrocatalyst

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Efficient and economical conversion of electricity from the sustainable but intermittent energy sources (*e.g.*, wind and sunlight) into H_2 fuel by the electrochemical splitting of water is considered one of the great challenges of chemistry.[1] Two reactions are involved in water splitting, and they are hydrogen evolution reaction (HER) at the cathode and OER at the anode. The OER is a complex four-electron oxidation process and suffers from a sluggish kinetics, which leads to considerable overpotentials and consequently significant efficiency losses.[2] Current commercial water electrolyzers rely on the use of ruthenium (Ru) and iridium (Ir) oxides as OER catalysts but they have limited availability and are expensive.

Recently, a great many alternative OER electrocatalysts based on abundant 3d metals (Fe, Co, Ni, Mn) have been developed with the hope of constructing efficient and economical electrolytic systems. Among these promising catalysts, Ni-containing materials have garnered special attention because of their abundance and low cost, as well as their moderate OER overpotential under alkaline conditions. High OER activity has been achieved with, for instance, Ni oxides, Ni-containing mixed-metal oxides, and various Ni-containing perovskite.[3-5] However, $Ni(OH)_2$, a widely used electrode material in alkaline batteries, has not received adequate attention in the field of water oxidation, possibly due to the fact that parasitic OER must be suppressed during battery cathode charging process.[6]

In this work, weinvestigate the utilization of $Ni(OH)_2$ nanocrystals as highly active and stable OER catalyst in alkaline media. We have synthesized a particular form of $Ni(OH)_2$ that exhibit excellent OER activity and stability in 0.1 M KOH electrolyte (pH = 13) that compare favorably with the state-of-the-art ruthenium oxide (RuO_2) catalyst. Additionally, by comparing the performance with several other forms of $Ni(OH)_2$ nanocrystals, we experimentally show that the particular form of $Ni(OH)_2$ is a superior OER catalyst. These results raise great possibilities for the design of effective and robust OER electrocatalysts by using cheap and easily prepared $Ni(OH)_2$ functional materials.

REFERENCES

[1] T. R. Cook, D. K. Dogutan, S. Y. Reece, Y. Surendranath, T. S. Teets, D. G. Nocera, *Chem. Rev.* **2010**, *110*, 6474.
[2] H. Dau, C. Limberg, T. Reier, M. Risch, S. Roggan, P. Strasser, *ChemCatChem*, **2010**, *2*, 724.
[3] E. L. Miller, R. E. Rocheleau, *J. Electrochem. Soc.* **1997**, *144*, 1995.
[4] R. D. L. Smith, M. S. Prévot, R. D. Fagan, Z. P. Zhang, P. A. Sedach, M. K. J. Siu, S. Trudel, C. P. Berlinguette, *Science* **2013**, *340*, 60.
[5] J. O. Bockris, T. Qtagawa, *J. Electrochem. Soc.* **1984**, *131*, 290.
[6] J. Chen, D. H. Bradhurst, S. X. Dou, H. K. Liu, *J. Electrochem. Soc.* **1999**, *146*, 3606.

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