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Development of Earth-Abundant Electrocatalysts for Efficient and Durable Water Splitting

Abstract

Water splitting has been proposed to be a promising approach to renewable energy storage through converting the off-peak solar or wind energy to hydrogen fuels. Presently, one of major challenges facing widespread deployment of water splitting devices is their high cost, which primarily results from the use of precious and scare noble metal catalysts. Following our previous success in fabricating self-supported transition metal phosphide (TMP) electrodes to catalyze the hydrogen and oxygen evolution reactions (HER & OER) [1-4], we recently found that the catalytic performance of TMP nanoparticles (NPs) for the HER or OER can be improved by fine-tuning the NP's shape and composition as well as by synergy with other catalytic materials.

In this presention, I will showcase three examples: 1) Hollow CoP octahedron (OCH) nanostructures with well-defined exposed crystal facets [5]. The hollow CoP OCH NPs were prepared by solution phase synthesis of CoO OCH precursors, followed by a post-phosphorization treatment and subsequent chemical etching process. They show excellent electrocatalytic performance for the OER, substantially outperforming CoP nanospheres without any preferentially exposed facets. 2) Trends in the OER activity of TMP catalysts [6]. We have investigated the alkaline OER electrolysis of a series of TMP catalysts and observed a notable trend in OER activity which follows the order of FeP < NiP < CoP < FeNiP < FeCoP < CoNiP < FeCoNiP. Our results show that the introduction of a secondary metal(s) to a mono-metallic TMP can remarkably boost the OER performance. This promotional effect can be ascribed to the enhanced oxidizing power of bi- and tri-metallic TMPs that can facilitate the formation MOH and chemical adsorption of OH^- groups, which are rate-limiting steps for these catalysts according to our Tafel analysis. 3) RuCoP nanoclusters showing superior HER performance in alkaline solution [7]. The RuCoP clusters were prepared by wet chemical reduction of metal cations followed by a low-temperature phosphorization treatment. When used to catalyze the HER, they show exceptional activity with a very low overpotential (η) of 23 mV to reach -10 mA cm^{-2} and a high turnover frequency (TOF) value of 3.85 s^{-1} at η = 100 mV. The superior HER performance can be attributed to the partial electron transfer from CoP to Ru, which substantially improves the HER kinetics on active Ru sites.

References

[1] X.G. Wang, Y.V. Kolen'ko, X.Q. Bao, K. Kovnir, L.F. Liu, Angew. Chem. Int. Ed., 54 (2015) 8188.

[2] X.G. Wang, W. Li, D.H. Xiong, D.Y. Petrovykh, L.F. Liu, Adv. Funct. Mater., 26 (2016) 4067.

[3] W. Li, X.F. Gao, X.G. Wang, D.H. Xiong, P.P. Huang, W.G. Song, X.Q. Bao, L.F. Liu, J. Power Sources, 330 (2016) 156.

[4] W. Li, X.F. Gao, D.H. Xiong, F. Xia, J. Liu, W.G. Song, J.Y. Xu, S.M. Thalluri, M.F. Cerqueira, X.L. Fu, L.F. Liu, Chem. Sci. 8 (2017) 2952.

[5] J.Y. Xu, J.J. Li, L.F. Liu, under preparation

[6] J.Y. Xu, J.J. Li, D.H. Xiong, B.S. Zhang, Y.F. Liu, K.H. Wu, I. Amorim, W. Li, S.M. Thalluri, L.F. Liu, submitted to Nano Lett.

[7] J.Y. Xu, J.J. Li, T.F. Liu, K. Yu, Y.F. Liu, D.H. Xiong, K.H. Wu, I. Amorim, S.M. Thalluri, W. Li, P.J. Ferreira, L.F. Liu, under preparation

Figures

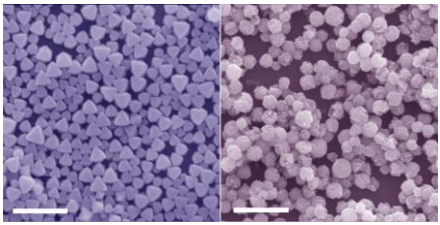

Figure 1: (left) CoP octahedron nanoparticles. (d) porous CoP nanospheres.