Platinum electrocatalysts with ultra-low metal loadings for promoting hydrogen evolution reaction

Taneli Rajala, Rasmus Kronberg, Kari Laasonen, Tanja Kallio

Department of Chemistry and Materials Science, School of Chemical Engineering, Aalto University, P.O. Box 16100, FI-00076 Aalto, Finland

E-mail of corresponding author: tanja.kallio@aalto.fi

Abstract

Solar and wind based energy supply will increase from the current level by more than one decade by the year 2040 [1], which lays foundation for the hydrogen economy concept where hydrogen serves as an energy carrier. Hydrogen utilization requires, however, introduction of efficient, durable and economically feasible electrochemical conversion of electrical energy into hydrogen bond energy. Electrochemical water splitting can meet these expectations if its key components, electrocatalysts, can be improved.

Today scarce platinum group metals (PGMs) are utilized to electrocatalyze the hydrogen evolution reaction. In addition to PGM availability and cost issues, these electrocatalysts suffer from inadequate durability because of the altering operation conditions induced by intermittent nature of solar and wind energy technologies.

Single-walled carbon nanotubes (SWNTs) have several beneficial properties needed for electrochemical applications: high conductivity, good chemical and electrochemical durability and appropriate properties for fabricating 3D electrodes [2]. Here, the unique morphology of SWNTs contributes to achieve material with ultra-low loadings Pt nanowires (PtNW). For the hydrogen evolution reaction (HER) in aqueous electrolyte, with ultralow Pt content of 340 ng_{Pt} cm^{-2} this kind of a material reaches catalytic activity comparable to that of state-of-the-art supported Pt with a notably higher Pt content (38,000 ng_{Pt} cm^{-2}). Furthermore, at the cathode of a proton-exchange-membrane electrolyzer generating stable voltage for more than 2,000 h at high current density it successfully competes with the state-of-the-art construction but with one tenth of Pt mass loading.

The high activity and excellent durability is attributed to favorable PtNW interaction with the SWNTs as well as exposed PtNW edge-sites which adsorb hydrogen optimally and help to alleviate repulsive interactions on the nanowire surface. In addition, the metallic nature of Pt, morphological effects and enhanced surface wetting contribute positively to the performance.

Key words: hydrogen evolution, ultralow Pt, Pt nanowire, carbon nanotube

References

[1] Annon., World Energy Outlook. Part B. Special focus on renewable energy. IEA 2016.

[2] M. Tavakkoli, *et al. ACS Catal*. 7 (2017) 3121.