The Effect of Ruthenium Content on the Service Lifetime of Ti/RuO$_2$-Sb2O$_5$-SnO$_2$ DSA for Oxygen Evolution

By

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Abstract

This work explores the opportunity to reduce the cost and enhance the stability of RuO$_2$-based electrocatalyst for oxygen evolution reaction by coating ternary oxide RuO$_2$-Sb$_2$O$_5$-SnO$_2$ on chemically stable titanium support. An active and stable type of Ti/RuO$_2$-Sb$_2$O$_5$-SnO$_2$ dimensionally stable anode (DSA) composites of different mole ratios of ruthenium which prepared by using thermal deposition method were studied. The metal oxides coating was maintained around 15 g m$^{-2}$. In this ternary oxide coating, RuO$_2$ serves as the catalyst, SnO$_2$ as the dispersing agent, and Sb$_2$O$_5$ as the dopant. The morphology by SEM showed that 10%, 20% and 30% ruthenium samples were less likely to lose their coating layers from detachment, the compact and uniform surface morphology that indicates a favorable dispersion of species. Further increase of ruthenium content, surface structure with more agglomerated particles and the coating surface becomes less compact. The microstructure by XRD showed that both crystallinity and crystal size decreased with the addition of tin and antimony, which suggest larger surface areas were available. Effects of ruthenium content on Ti/RuO$_2$-Sb$_2$O$_5$-SnO$_2$ anodes in terms of both catalyst activity and the catalyst corrosion for oxygen evolution reaction were established. The electrochemical characterization of these electrodes have been performed in acid medium, and the reversibility, electrochemical porosity (related to voltammetric charge), kinetic parameters (related to Tafel measurements) and electrochemical resistance (related to electrochemical impedance spectroscopy) have been established. The best activity performances were achieved by 50% and 75% nominal ruthenium content, which $q_{ct}$ were approximately equal to 1. The 50% ruthenium sample showed the lowest porosity value, which indicates it is easier to access active sites surface. There are two Tafel slopes in the low regions (31-44 mV dec$^{-1}$) and high potential regions (57-186 mV dec$^{-1}$) of Ti/ RuO$_2$-Sb$_2$O$_5$-SnO$_2$ electrodes, respectively. Moreover, the accelerated service lifetimes of the DSA could reach up to 422 hours in 3 M H$_2$SO$_4$ solution under a current density of 5,000 A/m$^2$ at 25°C, which is equivalent to more than 5.74 years for normal electroflotation at 25°C. The electrode service lifetime for high temperature condition test showed that this electrode with the 30% ruthenium gives an average accelerated service lifetime as high as 170 hours at 70°C, which is estimated to be over 2.38 years working at 70°C under normal electroflotation conditions. These results showed that the Ti/RuO$_2$-Sb$_2$O$_5$-SnO$_2$ electrode is a stable anode in industrial applications.

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