An electrode of self-assembly Co-Al layered double hydroxides for water oxidation

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Abstract:

Hydrogen is the most promising alternative energy source because water is the only production from the oxygen evolution reaction (OER). However, it requires input of a large amount of energy to drive the reaction. In recent years, scientists are trying to develop the OER catalysts with highly efficient electrocatalytic activity, low cost and environmentally friendly to replace precious catalysts, such as RuO_2 and IrO_2. Here we report that electrode of Co-Al layered double hydroxides (CoAl-LDHs) shows excellent OER activity in alkaline medium. The outstanding OER activity of the CoAl-LDHs can be attributed to their special layered structure and electrochemistry characteristics.

Keywords: Oxygen evolution reaction, layered double hydroxides, electrocatalyst.

1. Introduction

LDHs were two-dimensional (2D) anionic clay materials which represented as the general formula $[M_{1-x}^{2+}M_x^{3+}(OH)_2]^{x+}[A_{x/n}]^{n-}\cdot mH_2O$.[1] LDHs meet specific requirements for different experiments so they can applying on many kind of fields, such as catalyst, electrochemical and biochemical science.[1,2] In the recent years, environmental issues have been gradually emphasized. Thus, how to apply LDHs to produce green energy was very essential.

Water electrolysis has recently emerged as one of the most attractive approaches to realize efficient energy conversion and storage. It consists of two half reactions, namely OER and hydrogen evaluation reaction (HER). An effective OER electrocatalyst is the key to accelerate the reaction, lower the overpotential and thus raise the energy conversion efficiency.[3]

2. Experimental

In this study, the CoAl-LDHs nanosheet array on titanium foam was synthesized by a simple hydrothermal method (Fig. 1a). Firstly, the aqueous solution and the titanium foam (about 2 cm × 3 cm) were transferred to a Teflon-lined stainless-steel autoclave, which was sealed, maintained at 120°C for 12 hours. The CoAl-LDHs nanosheet array was synthesize by co-precipitation, which resulted in a pink coating on the surface of the titanium foam. After that, we controlled three different calcination temperatures (250, 300 and 350°C) and calcined for 2 hours. The corresponding sample was designated as CoAl-LDH-cX (X = 250, 300, and 350) and X means the calcination temperatures.

Then films were characterized by SEM, TEM, BET and XRD for its microstructures and morphologies. All the electrochemical measurements were performed on an electrochemical workstation in 1M KOH aqueous solution at room temperature. They were experimented for electrochemical properties by CV, CP, EIS, IT-Curve and LSV.

3. Results and discussion

Through this one-step hydrothermal method, we successful obtained the electrode of CoAl-LDH (Fig. 1a). Different from the traditional method, we didn’t use any adhesion to stick the substrate and in this experiment, there are no substrate restrictions because in Fig. 1d and 1e are nothing different when we used the same conditions on nickel foam and conductive glass. Fig. 1b SEM image shows that the array consisted of regular hexagonal nanosheets, typically 0.1 μm in thickness and its porous structure is form the interstices between the nanosheets.

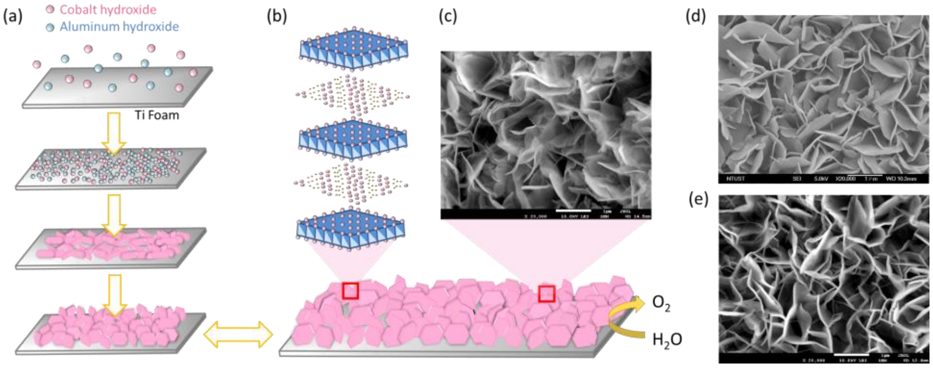

Figure 1. (a) Schematic of the formation of CoAl-LDH film on titanium foam as the OER working electrode and (b) the structure which zooms in a small region in (a). (c) SEM image of CoAl-LDH film. Synthesized CoAl-LDH film under the same conditions of the experiment on (d) nickel foam and (e) conductive glass.

Electrochemical characterization of the different calcination temperature CoAl-LDHs are presented in Fig. 2. Fig.2a showed the cyclic voltammogram (CV) curves at scan rate of 1 mV/s with a potential range of -0.5 to 0 V in 4 M KOH solution. CoAl-LDH-c300 had the highest specific capacitance was calculated to be 251.1 F/cm^3. The electrocatalytic activity direct the OER was investigated in a typical three-electrode setup by using CoAl-LDH as a working electrode in O_2-saturated 0.1 M KOH. The polarized curves were recorded using linear sweep voltammetry (LSV) and collected the situation of the CoAl-LDHs by Chronoamperometry (CP). As shown in Fig.2b and 2c, CoAl-LDH-c300 only needs an overpotential of 290 mV to generate 10 mA/cm^2 current density and relatively stable.

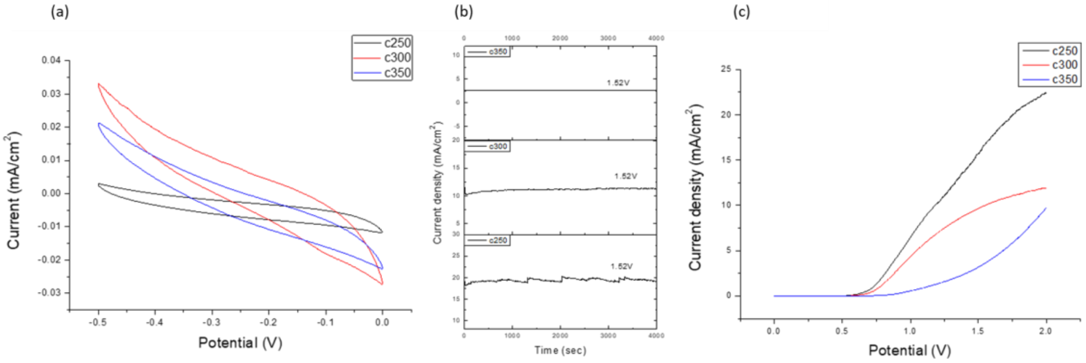

Figure 2. Electrochemical characterization of the different calcination temperature CoAl-LDHs (c250, c300 and c350). (a) CV curves of the CoAl-LDHs under same scan rate of 1 mV/s. (b) CP curves of CoAl-LDHs under same potential of 1.52 V. (c) LSV curves of the CoAl-LDH electrodes for OER.

4. Conclusions

In summary, we synthesized CoAl-LDH on titanium foam, illustrating its potential as a binder-free high-active electrocatalyst for OER. CoAl-LDH-c300 only needs overpotential of 290 mV to generate 10 mA/cm^2 current density, large current density and excellent ability, which compare to the precious metal catalyst. This kind of outstanding OER behavior can be attributed to the nanoarray formation, layered structure and special electrochemistry characteristics of CoAl-LDHs. Therefore, our study provides a simple method and new direction to synthesize LDHs toward catalytic and application for high-performance water splitting.

References

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