Abstract

In the past few years, a significant amount of efforts has been put to address the global energy challenges by developing various advanced energy conversion and storage devices. In this regard, nanostructured materials play an important role as compared to their bulk counterparts due to their unique properties. Hence designing and developing low cost, efficient and durable materials is needed in the energy industries. For this, several transition metal oxides and hydroxides have been studied because of their multiple oxidation states and stability. Among them, cobalt-based oxides and hydroxides have received considerable attention for energy applications. The synthesis, characterization and applications of cobalt based oxides/hydroxide nanomaterials are reported in the present thesis. Firstly, diverse Co_3O_4 nanostructures (urchin-like, flower-like and cubes) are synthesized using a solution-based microwave-assisted hydrothermal technique by varying reaction temperature, microwave power, precursor $[Co(NO_3)_2{\cdot}6H_2O]$ concentration, and concentration of shape controlling agent followed by annealing. The as-synthesized Co_3O_4 nanostructures are used as active electrode materials for supercapacitor application and the detailed mechanism has been discussed. The synthesis of $Co(OH)_2$ nanosheets upon $Cu(OH)_2$ nanobelts heterostructure through chemical etching and electrodeposition process has been demonstrated at room temperature and used as an electrode material for fabricating a binder-free supercapacitor device. Moreover, a bimetallic transition metal hydroxide, i.e., $CoSn(OH)_6$ (CS) cubes synthesized at room temperature and is demonstrated as oxygen evolution reaction (OER) electrocatalysts. To improve the OER activity, composite materials are prepared with varying amounts of g-C_3N_4 (gCN) and an optimal gC_3N_4 amount (CS/gCN100) shows the highest OER activity. Moreover, a phase-controlled synthesis of $Co(OH)_2$ nanostructures, i.e., α-$Co(OH)_2$ and β-$Co(OH)_2$ has been carried out to study their OER activity. Interestingly, the α-$Co(OH)_2$ exhibited superior OER catalytic activity owing to its more number of oxygen vacancies than β-$Co(OH)_2$. The best performance OER electrocatalyst as anode has been evaluated using Pt/C as the cathode as two-electrode configuration and compared with benchmark Pt/C ∥ IrO_2 for overall water splitting. This thesis work primarily emphasizes on the synthesis of cobalt-based oxides and hydroxides nanomaterials and their electrocatalytic and energy storage application.

Keywords: Cobalt oxide; cobalt hydroxide; cobalt tin hydroxide; asymmetric supercapacitor; heterostructure; oxygen vacancy; water splitting.