Pseudo Two Dimensional Nano-Structures of Cerium Based Oxides for Energy Applications

Abstract

Self-assembled hierarchical nanostructures are gradually replacing most of the traditional nanostructures for application as supercapacitor electrodes. These morphologies have higher surface area, tunable porosity and packing density. Modulating the interfacial interactions and subsequent particle assembly, occurring at the water-and-oil interface in inverse mini emulsions, are amongst the best strategies to stabilize hollow nanostructures. By controlling the diffusion and reaction kinetics, the dimension of the hollow cavity can be easily tuned. This thesis presents a successful strategy to visualize various hollow structures as pseudo-2D nanostructures. To visualize the hollow particles as 2D nanostructure, LAMMPS software is extensively used. Hollow CeO_2 is chosen as a model electrode material because of its high electrochemical potential, large theoretical specific capacitance, greater structural and thermal stability. To eliminate its disadvantage of poor conductivity, use of Cu doped CeO_2 is proposed as the way forward. The synthesised materials are characterized using a large number of characterization methods such as: XRD, XPS, SEM, TEM, BET, Zeta, DLS, CV, CD, Raman, FTIR, I-V, etc.

CeO_2 hollow structures show impressive electrochemical response, with almost ~3 fold higher specific capacitance in 1 A/g current density, in comparison to solid CeO_2 nanoparticles in different electrolytes (e.g. 1M KOH, 1M Na_2SO_4 and 1M H_2SO_4).

The electrochemical performance of the asymmetric supercapacitors using hollow CeO_2 as a positive and 2D graphite carbon nitride (gC_3N_4) as a negative electrode is presented discussed in details. The performance of such a device can be further improved by using a redox additive modified electrolytes. $K_3Fe(CN)_6$ is used as the redox additive to modified the performance of pristine 1M KOH electrolyte. Nearly 50% increment can be obtained in the specific capacitance by using modify electrolytes. The electrochemical performances of the asymmetric device under a varying of external factors such as temperature, magnetic field and external frequency are also reported for the first time.

Keywords: 2D structure, hollow nanoparticles, doping, redox additives, non-ambient condition, metal oxides, supercapacitor