Thesis title:

$Ni_{1-x}Co_xFe_2O_4$ ($0.0 \leq x \leq 1.0$) Based Nanostructures for High Performance Supercapacitors

ABSTRACT

Mixed metal oxides are gradually gaining prominence as electrode materials for supercapacitors. Such mixed metal oxides, consisting of more than one transition metals, allow synergistic contributions from each redox element in the material. This brings significant enhancement in the pseudocapacitance value. The rich redox chemistry, easy synthesis process, cost-effectiveness and environmentally benign nature of these mixed metal oxides are other advantages, useful for supercapacitor applications. Amongst the different mixed metal oxides, inverse spinel ferrites are being extensively investigated. This thesis deals with the use of $NiFe_2O_4$ and $Ni_{1-x}Co_xFe_2O_4$ ($0.0 \leq x \leq 1.0$) as efficient electrode materials for pseudocapacitors. $NiFe_2O_4$ has an inverse spinel structure, where Ni^{2+} occupies the octahedral sites while Fe^{3+} favours both the octahedral and tetrahedral sites according to the law of minimization of the crystal field stabilization energy (CFSE). The structure allows the hopping of electrons, a phenomenon that makes them excellent for electrochemical activity.

Out of the different compositions, it is shown that the $Ni_{0.5}Co_{0.5}Fe_2O_4$ has the best performance. The reasons driving a high electrochemical performance in this composition are discussed in detail. A new theoretical model is also proposed to explain the change of the diffusive nature of the electrolyte ions across the SEI, which leads to high redox activity in the materials reported in the thesis. To further increase the specific capacity value, a strategy of using redox additive modified electrolytes is proposed. The fruitfulness of the strategy is established by using $K_3[Fe(CN)_6]$and KI as redox additives in pure 3 M KOH electrolyte. The discharge capacity jumps from ~ 213 F g^{-1} to ~ 476 F g^{-1} when the pristine 3 M KOH electrolyte is modified with optimized concentration of $K_3[Fe(CN)_6]$. For the case of KI modified electrolyte, the value of specific capacitance increases from ~ 213 F g^{-1} to ~ 260 F g^{-1}. Interestingly, the electrochemical performance of all the synthesized materials (i.e. α-Fe_2O_3, NiO and $Ni_{1-x}Co_xFe_2O_4$ ($0.0 \leq x \leq 1.0$)) can be tuned by varying the external (applied) magnetic fields. The usefulness of these results for industrial applications are also presented in the thesis.

Keywords: Supercapacitors, Pseudocapacitors, Metal oxides, Inverse Spinel Ferrite, Magnetic Supercapacitors, Redox Additives.