High Performance Na-ion Supercapacitors using $NaFePO_4$ and Nanostructured Carbons

Abstract

The intrinsic limitation of a renewable energy generation system i.e. “intermittency” is mitigated by the use of energy storage technologies. Li-ion batteries and supercapacitors are two such energy storage technologies, which are attracting the maximum interest over the last few decades. The former delivers high energy density while the latter is considered to be more suited for applications where higher power density is required. Hybrid systems, showing the response characteristics of both these technologies, are also now being reported. Owing to limited resources, economics, and geopolitical issues related to lithium-ore, technologies based on other similar ions are being extensively investigated. These include batteries and supercapacitors based on Na-, K-, Zn-, S-, or F- ions.

Supercapacitors, with their capacity to deliver high power, large cycle life, and resilient mechanism to counter surge / spikes, and easy fabrication protocols are slowly becoming an integral component of renewables based energy sector. *The thesis deals with the work carried to obtain high performance supercapacitors based on Na-ion based electrode materials and their combination with different carbon nanostructures such as particles, paper, nanotube, quantum dots, etc.*

$NaFePO_4$, with hitherto unreported hollow morphologies, are synthesized and suggested as a promising electrode material for Na-ion supercapacitors. These types of morphologies have been recently suggested to have much higher response characteristics than their solid counter parts. The particles were characterized using a large number of techniques such as: XRD, FESEM, TEM, Raman, FTIR, BET, XPS, Pore Size Analysers, etc. The results of these studies are discussed before the useful of $NaFePO_4$ in supercapacitors is established. It is also unequivocally shown that Na-ion based supercapacitors can only become useful if a proper carbon-based negative electrode is chosen. Combination of $NaFePO_4$ with a large number of carbon structures such as: activated particles, microspheres, nanospheres, sheets, tubes, rGO, GO to quantum dots were investigated during the work. It is found that the combination of $NaFePO_4$ and rGO delivers the best results. It is shown that varying temperature, magnetic field, or external vibrations can lead to significant performance modulation. Theoretical models are also proposed to explain these results.

Keyword: Na-ion supercapacitor, electrochemical activity, redox additive, asymmetric device, non-ambient condition