Development of Transition Metal Containing Phosphate Based Pseudocapacitive Electrodes for the Fabrication of High Performing Hybrid Supercapacitors

A thesis submitted in partial fulfillment for the Award of Degree

Doctor of Philosophy

By

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I, ***KRISHNA GOPAL NIGAM***, certify that the work embodied in this thesis is my own bonafide work carried out by me under the supervision of ***Dr. Preetam Singh*** form ***July 2019*** to ***Dec 2024***, at the ***Department of Ceramic Engineering,*** Indian Institute of Technology (BHU), Varanasi. The matter embodied in this thesis has not been submitted for the award of any other degree/diploma.

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Chapter 6

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List of Abbreviations

XRD	X-ray Diffraction
HR	SEM-High-Resolution Scanning Electron Microscope
HR-TEM	High-Resolution Transmission Electron Microscope
TGA	Thermogravimetric analysis
FTIR	Fourier transform Infrared Spectroscopy
XPS	X-ray Photoelectron Spectroscopy
BET	Brunauer, Emmett, and Teller
CV	Cyclic Voltammetry
ASCs	Asymmetric Supercapacitors
HSCs	Hybrid Supercapacitors
EDLC	Electrochemical double layer capacitor
EIS	Electrochemical impedance spectroscopy
ES	Electrochemical supercapacitor
C_{sp}	Specific capacitance
A, mA (unit)	Ampere, milliamp
AC	Activated Carbon
AM	Active mass
C, μC (unit)	Coulomb, microcoulomb
C	Capacitance
$C^{+/}R^{+}$	Cationic species in electrolyte
C*	Complex differential capacitance
C_{+ve}	Capacitance of positive electrode
C_{-ve}	Capacitance of negative electrode
C_{Cell}	Overall cell capacitance
C_{Diff}	Capacitance from diffuse layer
C_{dl}	Capacitance from double layer
C_{g}	Gravimetric capacitance
C_{H}	Capacitance from Helmholtz plane
C_{IH}	Capacitance from inner Helmholtz plane
C_{OH}	Capacitance from outer Helmholtz plane
e-	Electron
ε	Permittivity of vacuum
E	Electrode potential

$E°$	Standard electrode potential
E_{Total}	Total energy stored in capacitor
f	Frequency
F	Faraday constant
F, mF, μF(unit)	Farad, millifarad, microfarad
g, mg, μg(unit)	Gram, milligram, microgram
h (unit)	Hour
Hz, mHz, kHz (unit)	Hertz, millihertz, kilohertz
I	Current
K (unit)	Temperature in Kelvin
K	Boltzmann's constant
M	Mass of active materials
m, cm, μm, nm (unit)	Meter, centimeter, micrometer, nanometer
M	Molar concentration
Q	Charge stored
V	Voltage
V_{max}	Maximum voltage
V_{Min}	Minimum voltage
W (unit)	Watt
Wh (unit)	Watt hour
wt%	Weight percentage
ω	Angular frequency
X	Fraction of ion occupancy in lattice
z	Number of electrons transferred in redox reactions
Z*	Total impedance
Z'	Real component of impedance
Z''	Imaginary component of impedance
ΔV	Voltage window
°C (unit)	Temperature in Celsius
θ_H	Surface coverage of H_+ in underpotential deposition