Dedication

I dedicate this work to my wife for her unconditional love and support and have always been there for me.

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Shibsankar Dutta
02/09/19
Signature of the Candidate with date

Abstract

Two dimensional (2-D) nanomaterials have drawn considerable attention to the evolution of supercapacitor electrodes for high performance flexible energy storage device applications due to their high electro-active sites, high specific surface area, macro mechanical flexibility, well-behaved electrical properties etc. The thesis entitled "**2-D Nano Materials and their Hybrids as Supercapacitor Electrodes for Energy Storage Applications"** encompasses a detail report on the development of some 2-D nanomaterials through different synthesis routes and their applications in supercapacitor energy storage. More precisely, this dissertation highlights the successful synthesis of some 2-D transition metal oxides (TMOs) like MoO_3, MnO_2, RuO_2, metal dichalcogenides (MoS_2), BiOCl nanoplates, vanadyl phosphate ($VOPO_4$) and their composites with graphene, single and multi-wall carbon nanotubes (SWCNT, MWCNT) etc. and their applications as supercapacitor energy storage devices. The prepared samples have been thoroughly characterized by FESEM, TEM, XRD, XPS, AFM BET, Raman and etc.

In this work, a facile large scale production of TMOs nanosheets by exfoliation in ethanol-water mixed solvent instead of using highly toxic organic solvents has been demonstrated. After optimization, this method gives high concentration (0.42 mg/ml, 0.47 mg/ml and 0.40 mg/ml for MoO_3, MnO_2 and RuO_2 respectively) stable dispersion of TMOs nanosheets. Thin flexible solid state supercapacitors based on SWCNT /TMOs nanosheets composites showing a large specific capacitance and high energy density. In addition, a planner supercapacitor based on SWCNT/MnO_2 shows an improved electrochemical performance with excellent stability under different bending condition. Thin flexible films of BiOCl/MWCNT composites have been prepared with varying the weight percentage. Among various compositions, 60% BiOCl loaded electrodes delivers superior electrochemical performance. Instead of gold we have used SWCNT network as a current collector which will be helpful to make transparent flexible supercapacitor with high energy density for future application $BiVO_4$/rGO hybrid nanostructure based symmetric supercapacitor exhibits better performance in solid electrolyte. MoS_2/rGO hybrids thin film supercapacitor and MWCNT/$VOPO_4$ hybrid supercapacitor are also deliver improved energy storage performance.

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List of Abbreviations

0D, 1D, 2D, 3D	Zero, One, Two, Three Dimensional
	A
AFM Microscope	Atomic Force
	B
$BiVO_4$	Bismuth vanadate
BiOCl	Bismuth oxychloride
	C
CV	Cyclic voltammetry
CNTs	Carbon nanotubes
CMG graphene	Chemically modified
Co_3O_4	Cobalt oxide
	D
DMSO	Dimethyl sulfoxide
DMF	Dimethylformamide
	E
EDLC capacitor	Electric double layer
ESPW potential window	Electrochemical stable
ESR resistance	Equivalent series
EDX	Energy dispersive X-ray
EIS impedance	Electrochemical spectroscopy
ECS supercapacitor	Electrochemical
	F
FESEM electron microscope	Field emission scanning
Fe_3O_4, Fe_2O_3	Iron Oxide
FSSSC symmetric supercapacitor	Flexible solid state
	G
GA	Graphene analogue
GO	Graphene oxide
GCD discharging	Galvanometric charging
	H
HRTEM Transmission Electron Microscope	High-resolution
HSP parameter	Hansen solubility
HSCs	Hybrid supercapacitors
H_2SO_4	Sulphuric acid
	I
IHP	Inner Helmholtz plane
IrO_2	Iridium (IV) oxide
	K
KCl	Potassium Chloride
KI	Potassium Iodide
KOH	Potassium hydroxide
	L
LIB	Lithium ion battery

M

MoO_3	Molybdenum Trioxide
MnO_2	Manganese (IV) Oxide
MWCNT nanotube	Multiwall Carbon
MXenes and/or nitrides	Transition metal carbides

N

Na_2SO_4	Sodium sulfate
NiO	Nickel oxide
NMP	N-Methyl-2-pyrrolidone
NaOH	Sodium Hydroxide

O

OHP	Outer Helmholtz plane

P

PET Terephthalate	Polyethylene
PSCs	Pseudo supercapacitor
PVA	Polyvinyl Alcohol
PVP	Polyvinylpyrrolidone
PEO	Polyethylene glycol
PAA	Polypolyacrylate
PVDF	Polyvinylidene fluoride
PEDOT: PSS	Poly(3,4-Ethylenedioxythiophene):Poly(Styrene-Sulfonate)

R

rGO	Reduced graphene oxide
RuO_2	Ruthenium (IV) Oxide
R_{ct}	Charge transfer resistance

S

SWCNT nanotube	Single wall carbon
SCs	Supercapacitors
SDS	Sodium dodecylsulphate
SNAP	Spin-on nano imprinting

T

TMOs	Transition metal oxides
TMDCs	Transition metal dichalcogenides

U

UV-Vis-NIR	Ultraviolet-visible-near infrared spectrophotometer

V

VS_2	Vanadium disulfide
$VOPO_4$	Vanadium phosphate
V_2O_5	Vanadium pent oxide

W

WS_2	Tungsten disulfide

X

XPS	X-ray photoelectron spectroscopy
XRD	X-Ray Diffractometer

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