Declaration

I hereby declare that the thesis entitled **"Reduced graphene oxide-poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate)-transition metal oxide based ternary nanocomposites as anode catalyst for methanol oxidation"**, submitted to the School of Sciences, Tezpur University in partial fulfillment of the requirements for the award of the Doctor of Philosophy in Physics, is a record of original research work carried out by me. Any text, figures, theories, results or designs that are not of my own devising are appropriately referenced in order to give due credit to the original author(s). All the sources of assistance have been assigned due acknowledgement. I also declare that neither this work as a whole nor a part of it has been submitted to any other university or institute for any degree, diploma, associateship, fellowship or any other similar title or recognition.

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All help received by her from various sources have been duly acknowledged.

No part of the thesis has been submitted elsewhere for award of any other degree.

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All help received by her from various sources have been duly acknowledged.

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Dedicated to

My beloved

Ma & Deuta

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Date: (Bhagyalakhi Baruah)

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List of Abbreviations

Abbreviation	Meaning
APS	Ammonium peroxydisulfate
BET	Brunauer-Emmett-Teller
BJH	Barret-Joyner-Halenda
CA	Chronoamperometry
CE	Counter electrode
CH_3OH	Methanol
CNF	Carbon nanofibre
CNT	Carbon nanotube
CO	Carbon monoxide
CO_2	Carbon dioxide
COH	Aldehyde
CP	Conducting polymer
CPE	Constant phase element
CQD	Carbon quantum dot
CV	Cyclic voltammetry
DI	Deionized water
DMFC	Direct methanol fuel cell
EDL	Electric double layer
EDX	Energy Dispersive X-ray
EIS	Electrochemical impedance spectroscopy
$FeCl_3$	Ferric chloride
GCE	Glassy carbon electrode
GO	Graphite oxide
HCO	Bicarbonate
HCOO	Formic acid
H_2O	Water
HRTEM	High resolution transmission electron microscopy
ITO	Indium tin oxide
LSV	Linear sweep voltammetry
MEA	Membrane electrode assembly

MnO_2	Manganese dioxide
MOR	Methanol oxidation reaction
MTMO	Mixed transition metal oxide
MWCNT	Multi-walled carbon nanotube
$NiMn_2O_4$	Nickel manganite
NiO	Nickel oxide
ORR	Oxygen reduction reaction
PA	Polyacetylene
PAni	Polyaniline
PEDOT	Poly(3, 4 ethylene dioxythiophene)
PEM	Proton exchange membrane
PEMFC	Proton exchange membrane fuel cell
PFSA	Perfluorosulfonic acid
PPy	Polypyrrole
PSD	Pore size distribution
PSS	Poly(styrenesulfonic acid)
Pt	Platinum
PTFE	Polytetrafluoroethylene
PTh	Polythiophene
PVP	Polyvinylpyrrolidone
RE	Reference electrode
rGO	Reduced graphene oxide
SCE	Saturated calomel electrode
SEM	Scanning electron microscopy
SHE	Standard hydrogen electrode
SWCNT	Single-walled carbon nanotube
TMO	Transition metal oxide
TPB	Triple phase boundary
WE	Working electrode
XRD	X-ray diffraction

List of Symbols

Symbol	Meaning
A	Surface area
C_{dl}	Double layer capacitance
D	Diffusion coefficient
ΔE_p	Peak to peak separation
E_{pa}	Anodic peak potential
E_{pc}	Cathodic peak potential
E_f^0	Formal potential
F	Faraday constant
i_0	Exchange current density
i_c	Capacitive current
i_f	Faradaic current
I_{pa}	Anodic peak current
I_{pc}	Cathodic peak current
k_s	Heterogeneous rate constant
N_A	Avogadro's number
R	Universal gas constant
R_{ct}	Charge transfer resistance
R_s	Solution resistance
r_k	Kelvin radius
r_p	Pore radius
S_{BET}	BET specific surface area
T	Temperature
t_a	Thickness of the adsorbed gas
v_m	Quantity of monolayer adsorbed gas
X_C	Capacitive reactance
X_L	Inductive reactance
Z	Electrochemical Impedance
Z'	Real Impedance
Z''	Imaginary Impedance

Z_W	Warburg impedance
α	Charge transfer coefficient
β	Tafel slope
Γ^*	Surface coverage
γ	Surface tension of liquid
δ	Thickness of Nernst diffusion layer
η	Overpotential
ν	Scan rate
σ	Warburg coefficient
φ	Phase shift
ω	Frequency