

Contents

Title	Pages
Certificate & Declaration by the Candidate by the Supervisor.....	ii-iii
Copyright Transfer Certificate.....	iv
Acknowledgement.....	v
Contents.....	ix
List of Figures.....	xiv
List of Tables.....	xxi
Preface.....	xxiii
1 Introduction.....	1
1.1 Overview of the Work.....	3
1.2 Fuel Cells: an overview	4
1.3 Types of Fuel Cell.....	5
1.4 Solid Oxide Fuel Cell (SOFC)	6
1.4.1 General Introduction	6
1.4.2 Operation of Solid Oxide Fuel Cells.....	9
1.5 Materials Selection for the Component of SOFC	10
1.5.1 Electrodes (Cathode and Anode)	10
1.5.2 Interconnect.....	12
1.5.3 Electrolyte.....	13
1.6 High and Intermediate Temperature Solid Oxide Fuel Cell	14
1.6.1 High Temperature Solid Oxide Fuel Cells (HT-SOFC)	14
1.6.2 Demerits of High Temperature Solid Oxide Fuel Cells	14
1.6.3 Intermediate Temperature Solid Oxide Fuel Cells (IT-SOFC).....	15
1.6.4 Merits of Intermediate Temperature Solid Oxide Fuel Cells.....	15
1.7 Factors Influencing Ionic Conduction of the Electrolyte.....	16
1.8 Perovskite's Oxide System	19

1.9	Types of Perovskite Oxides.....	22
1.9.1	$A^{1+}B^{5+}O_3$ Type Structure	22
1.9.2	$A^{2+}B^{4+}O_3$ Type Structure	23
1.9.3	$A^{3+}B^{3+}O_3$ Type Structure	23
1.10	Properties of Perovskite.....	23
1.10.1	Electrical properties	25
1.10.2	Magnetic Properties	27
1.10.3	Optical Properties.....	27
1.11	Applications of Perovskites	28
1.12	Protonic conducting oxides: principle and defect chemistry.....	30
1.12.1	Proton defect formation	30
1.12.2	Hydration thermodynamics of acceptor-doped perovskite oxides.....	32
1.12.3	Proton transport.....	36
1.12.4	Effects of defect-dopant association	37
1.12.5	Isotope effect.....	39
1.12.6	Mixed conductivity in proton conductors	41
1.13	Proton conducting oxides: Materials	44
1.13.1	Proton conductivity in acceptor-doped perovskite oxides.....	44
1.13.2	Proton conductivity in non-perovskite oxide and phosphates	48
1.13.3	Proton-conducting oxides: application in fuel cells.....	49
1.14	Objective of present investigation	50
2	Materials Synthesis and Characterizations	52
2.1	Synthesis of Materials	54
2.1.1	Mechanical Alloying Method	55
2.1.2	Citrate-Nitrate Auto-Combustion Method.....	58
2.1.3	Raw Materials	60
2.1.4	Preparation of Materials using Ball Milling	61

2.1.5	Calcination of Materials.....	62
2.1.6	Granulation and pelletizations	62
2.1.7	Sintering.....	62
2.2	Materials Characterization	63
2.2.1	Thermal analysis (TGA-DSC).....	63
2.2.2	Measurement of Density and Porosity.....	64
2.2.3	Phase Formation and Crystal Structure Studies by Powder X- ray Diffraction	65
2.2.4	Raman Spectroscopy.....	76
2.2.5	Fourier Transform Infrared Spectroscopy (FTIR)	78
2.2.6	Microstructure and Elemental Analysis.....	79
2.2.7	Optical Characterization Technique	87
2.2.8	Alternating current (AC) Electrical data analysis.....	90
3	Synthesis and Characterization of SrCeO ₃	100
3.1	Introduction	102
3.2	Experimental	103
3.3	Results and Discussions	104
3.3.1	Thermal Analysis (TGA-DSC) of mixture of raw material.....	104
3.3.2	Structural characterization using XRD	105
3.3.3	Microstructural and compositional analysis	108
3.4	Electrical characterization.....	110
3.4.1	By impedance spectroscopy.....	110
3.4.2	By DC conductivity measurements	115
3.4.3	Photoluminescence studies	117
3.5	Conclusions	118
4	Synthesis and characterization of Na ⁺ doped system SrCe _{1-x} Na _x O ₃ (x=0.0,0.02,0.04,0.06 and 0.10)	119
4.1	Introduction	121

4.2	Experimental	122
4.3	Results and Discussion.....	124
4.3.1	Thermal analysis (TG/DSC) of raw materials and their mixture.....	124
4.3.2	Phase analysis and structural characterization.....	127
4.3.3	Raman spectra analysis	133
4.3.4	Fourier Transform Infrared (FTIR) Analysis.....	135
4.3.5	UV-Visible Spectra Analysis.....	137
4.3.6	Microstructural studies.....	140
4.3.7	Electrical measurements	143
4.3.8	X-ray Photoelectron Spectroscopy (XPS) analysis.....	150
4.4	Conclusions	151
5	Synthesis and characterization of Gd ³⁺ doped system SrCe _{1-x} Gd _x O ₃ (x=0.0,0.02,0.04,0.06 and 0.10)	152
5.1	Introduction.....	154
5.2	Experimental	156
5.3	Results and Discussion.....	157
5.3.1	Phase analysis and structural characterization using XRD.....	157
5.3.2	Raman spectra analysis	163
5.3.3	FTIR analysis	166
5.3.4	Thermal analysis (TGA/DSC)	168
5.3.5	UV-Visible analysis	169
5.3.6	Microstructural and energy dispersive x- ray analysis	171
5.3.7	Impedance spectroscopy	175
5.3.8	X-ray photoelectron (XPS) measurements	180
5.4	Conclusion.....	182
6	Synthesis and characterization of La ³⁺ doped system SrCe _{1-x} La _x O ₃ (x=0.0,0.02,0.04,0.06 and 0.10)	184
6.1	Introduction.....	186

6.2	Experimental	187
6.3	Results and Discussions	188
6.3.1	Thermal analysis (TGA/DSC)	188
6.3.2	Phase identification using XRD.....	189
6.3.3	Raman Spectrum Analysis.....	194
6.3.4	Fourier Transform Infrared Spectroscopy (FTIR) analysis	196
6.3.5	UV-Visible Spectroscopy	197
6.3.6	Microstructural study using SEM	199
6.3.7	Transmission Electron Microscope (TEM) Analysis	202
6.3.8	Impedance spectroscopy	203
6.3.9	X-ray Photoelectron Spectroscopy (XPS) analysis.....	207
6.4	Conclusions	208
7	Conclusion and Future Scope	209
7.1	Summary of the thesis research work	211
7.2	New Directions and Future Perspectives	213
8	References.....	215