
LIST OF FIGURES

		Page No.
Chapter 1	Introduction and Literature Review	
Fig. 1.1	Energy demand (in Joule) and its consumption	1
Fig.1.2	Working principle of SOFC	5
Fig.1.3	Tubular SOFC configuration and planar design SOFC	6
Fig.1.4	(a) The major sources of ionic carriers in oxides and their respective mobilities compiled from literatures (b) The correlation of composition, microstructure, processing and electrical conductivity in polycrystalline materials under given temperature and surrounding atmosphere	12
Fig.1.5	Present Scenario of electrolytes	15
Fig.1.6	Perovskite structure ABO_3 and octahedron BO_6	16
Fig1.7	Ideal perovskite structure of LAO with AlO_6 octahedron	20
Chapter 2	Synthesis, Characterization and Analysis Techniques	
Fig. 2.1	Flow chart of auto-combustion synthesis	31
Fig. 2.2	Flow Chart of tape casting technique	32
Fig. 2.3	Mechanism and experimental setup of DTA/TGA	34
Fig. 2.4	Mechanism and experimental setup of X-ray diffraction	35
Fig. 2.5	Balance with density kit	36
Fig. 2.6	Mechanism, experimental setup and Grid of TEM	39
Fig. 2.7	Mechanism (left) and experimental setup of FESEM	40
Fig. 2.8	Mechanism of X-ray photoelectron spectroscopy and	42
Fig. 2.9	Conductivity spectra of a polycrystalline material	45
Fig. 2.10	Equivalent circuit for a polycrystalline ceramic sample and corresponding frequency response in the complex plane plots	48
Fig. 2.11	Computer controlled automated impedance analyzer setup along with sample holder and furnace	51
Chapter 3	Study of Structure and Ion Dynamics behavior in Lanthanum Aluminate	
Fig.3.1	Simultaneous DTA and TGA curve of ash prepared LAO	57

Fig.3.2	Powder X-ray diffraction pattern of (a) calcined (b) sintered powder of LAO and (c) Rietveld refinement of LAO	58
Fig.3.3	SEM micrograph of sintered pellet of LAO	59
Fig.3.4	(a)-(d) TEM image of calcined LaAlO ₃ sample	60
Fig.3.5	XPS of Lanthanum Aluminate	61
Fig.3.6	Conductivity spectra of LAO at a few temperatures. Symbols denote the experimental data points and the solid lines represent the fit to the data points with equation (1).The temperature shown in degree Celsius.	62
Fig. 3.7	Arrhenius representation of (a) dc conductivity and (b) the hopping frequency for LAO	63
Fig. 3.8	The dc conductivity, σ_{dc} vs. hopping frequency, ν_H for LAO	64
	Scaled conductivity spectra of LAO	
Fig. 3.9	Electric modulus spectra of LAO. Temperatures (°C)	65
Fig. 3.10	Scaled electric modulus spectra of LAO.	66
Fig. 3.11	Arrhenius representation of peak frequency of electric	67
Fig. 3.12	modulus spectra for LAO	68
Chapter 4	Study of structural and electrical properties and their correlation for Ba incorporated La_{0.9}Sr_{0.1}Al_{0.9}Mg_{0.1}O_{3-δ} in bulk and Tape casted Thin Film	
Fig.4.1	Tolerance factor of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ}	73
Fig.4.2	XRD pattern of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ} .	75
Fig.4.3	(a-c) Peak broadening and (d) intensity variation for (202) (012) and (110) peaks respectively	75
Fig.4.4	Oxygen Deficiency estimated from EDX; inset: (right bottom) shows atomic % of O; (left top) shows atomic % of Ba) in Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ} .	76
Fig.4.5	XPS spectra of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ}	77
Fig.4.6	Variation of Lattice parameters of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ}	78

Fig.4.7	Angular correlation between the grains and lattice unit cell	79
Fig. 4.8	Log log Impedance Nyquist plots of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-d} (LSAM) at 600 °C show normal Nyquist plot unable to resolve (b) Impedance Nyquist plots of B3 at 400, 500, and 600°C, (c) Scaling of conductivity	82
Fig.4.9	Correlation between the critical triangle structural parameter and the electrical parameters of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-d} .	83
Fig.4.10	Migration path for ionic conduction of oxygen ion has been mapped out using the correlation of bulk conductivity with A-A-B angle (β) and of dc conductivity with A-B-A angle (α)	84
Fig.4.11	(a) dc conductivity of Ba modified La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ} shows the relative ratio of ionic conductivity to total conductivity at 973K (b) shows variation of the ratio with temperature	86
Fig.4.12	Comparative XRD of sample La _{0.9} Sr _{0.1} Al _{0.9} Mg _{0.1} O _{3-δ} (a) freshly prepared sample and sample kept in ethanol for one month (b) at different temperatures	88
Fig.4.13	Comparison of synthesis techniques of the tape and the pellet of B1 sample	89
Fig.4.14	Structural analysis of tape and pellet of B1	89
Fig.4.15	SEM and EDX measurement of pellet and tape of B1	92
Fig. 4.16	Nyquist plot of (a) tape and (b) pellet of B1	93
Fig. 4.17	An equivalent circuit diagram of Nyquist plot (a) tape and (b) pellet	95
Fig. 4.18	log zI vs log f of (a) tape and (b) pellet	95
Fig. 4.19	(a) log (σT) vs 1000/T (b) log τ vs 1000/T for activation energy	97
Fig. 4.20	log (σ) vs log (v) (a) tape and (b) pellet of B1	99
Fig. 4.21	Variation of log (σ/σ_{dc}) vs log (v/v_0) for tape and pellet	100

Fig. 4.22	Arrhenius plot of tape and pellet	101
-----------	-----------------------------------	-----

Chapter 5 Study of structural and electrical properties and their correlation for Sm incorporated $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$

Fig.5.1	Tolerance factor of Sm substituted $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	104
Fig.5.2	XRD pattern of Sm substituted $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$ (b) Reitveld refinement of S1 sample (c) shifting of (110) peak for LAO, S0, S1, S3 and S5 sample	105
Fig.5.3	(a-b) Variation of Lattice parameters of Sm modified $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$ with tolerance factor	106
Fig.5.4	Oxygen estimated from EDX; inset: (right bottom) shows a deficiency of O in Sm modified $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	107
Fig.5.5	Correlation between the critical triangle structural parameter and the electrical parameters of Sm substituted $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	108
Fig.5.6	Variation of dc conductivity (σ_0) with temperature and transference number (T_f) with composition (inset)	110
Fig.5.7	(a) $\log\sigma$ vs $\log v$ at various temperature for LAO (a inset) Ghosh scaling for LAO (b) $\log\sigma$ vs $\log v$ at various temperature for 0.01 mol % Sm substituted LAO (S1). Line indicate the fitting through J P law and symbol indicates data points (c) Ghosh scaling for S1 sample at low T (c inset) after 500 °C (d) variation of n vs T	112
Fig.5.8	(a-e): Differential Impedance Of LAO and Sm substituted $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	113
Fig.5.9	(a) $\log Z $ vs $\log f$ of LAO and (b) Sm substituted LSAM, (c) activation energy curve (d) fractal exponent (k) vs temperature (°C)	114
Fig.5.10	activation energy curve for S0.	115
Fig.5.11	Variation of microstructure with temperature for LSSAM sample	117
Fig. 5.12	HT-XRD of LAO and $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	118

Fig.5.13	Rietveld refinement of LAO and S0 with R-3c and Pm3m symmetry	118
Fig. 5.14	(a) Bond angle ($^{\circ}$) and tilting variation with temperature ($^{\circ}$ C) (b) Variation of bond angle with temperature ($^{\circ}$ C) For LAO and $\text{La}_{0.9}\text{Sr}_{0.1}\text{Al}_{0.9}\text{Mg}_{0.1}\text{O}_{3-\delta}$	119
Fig. 5.15	Variation of tilting with critical triangle angle B-A-B (α) and A-B-B (β)	120
Fig. 5.16	XRD pattern of S0 in inert atmosphere (dash line) and in ethanol dipped @ 1 month	121
Chapter 6	Effect of Electrode Paste on Oxide Ions Path at interface using Pt and Ag on above System	
Fig. 6.1	X-ray diffractograms of the samples B0, B3 and S3	125
Fig. 6.2	(a - f) shows $\log \sigma$ vs $\log v$ for B0, B3 and S3 specimens with both cell configurations. The symbols indicate the data points and lines represent the fitting to the data through J P law	127
Fig. 6.3	Values of dc conductivity obtained from the fitting of ac conductivity data using J P law	128
Fig. 6.4	Variation of $\log \sigma/\sigma_0$ vs $\log v/v_0$ for B0 and B3	129
Fig. 6.5	Variation of $\log \sigma/\sigma_0$ vs $\log v/v_0$ for S3	130
Fig. 6.6	Variation of Exponent (n) with temperature for Ag/M/Ag and Pt/M/Pt cell configurations	131
Fig. 6.7	Impedance profile (Nyquist plot) at 600 $^{\circ}$ C for Ag/M/Ag and Inset shows Nyquist plot for Pt/M/Pt (b) Nyquist plot for Ag/M/Ag and Pt/M/Pt showing the difference in electrode contributions (c) Equivalent circuit for the Nyquist plots	132

Fig. 6.8	log Z vs log frequency plots to calculate the values of K	134
Fig. 6.9	Variation of the K Values with temperature	134
Fig. 6.10	Ratio of Activation energy for Ag/M/Ag and Pt/M/Pt. The variation of log σT vs $1000/T$	135
Fig. 6.11	Transport number for Ag/M/Ag and Pt/M/Pt specimens	138
Fig. 6.12	EDAX line profile for Ag/M/Ag and Pt/M/Pt specimen	139
Fig. 6.13	Pictorial representation for the motion of oxygen ions from the (a) Pt/M/Pt and (b) Ag/M/Ag	141
Fig. 6.14	Bond angle and octahedral-tilting angle as a function of temperature	142