## Contents

			Page No.	
	Acknowledgements			
	Preface			
Chapter 1	Introduction			
1.1	Introd	Introduction – SOLID STATE IONICS		
1.1	Worki	Working of a battery		
1.2	Device	Devices using FIC materials (Applications of FICs)		
	1.2.1	Gas sensors	6	
	1.2.2	Ion Selective Electrode	6	
	1.2.3	Supercapacitors	6	
	1.2.4	Battery material	7	
	1.2.5	Solid Oxide Fuel Cells (SOFC)	7	
1.3	Fast ic	on conducting materials	7	
	1.3.1	Lithium Ion Conductors	7	
	1.3.2	Sodium Ion Conductors	8	
	1.3.3	Silver Ion Conductors	8	
	1.3.4	Copper Ion Conductors	8	
	1.3.5	Fluorine ion conductors	8	
	1.3.6	Proton conductors	9	
	1.3.7	Oxygen Ion Conductors	9	
1.4	Properties of a Cathode Material		9	
1.5	Lithiu	m based Inorganic systems	10	
	1.5.1	Li <sub>4</sub> SiO <sub>4</sub> compounds and related phases	10	
	1.5.2	NASICON compounds	10	
	1.5.3	Lithium Rare Earth Titanate Perovskites	10	
	1.5.4	Composite Material	11	
	1.5.5	Lithium Metal Halides	11	
	1.5.6	LISICONs	11	
	1.5.7	Lithium Garnets	11	
1.6	LIPON, LISON and LIPOS glassy systems			
1.7	A brief introduction of NASICON materials			
1.8	Motivation for the present work 1			

	References			17
Chapter 2	Theor	21-50		
2.1	Theory about Solid State Reaction			23
	2.1.1	What are So	olid State Reactions?	23
	2.1.2	What is its i	relevance in Solid State Chemistry?	23
	2.1.3	Why are So	lid State Reactions difficult?	23
2.2	Experimental techniques			24
	2.2.1	X-ray Dif	fraction	24
	2.2.2	Density n	neasurements	26
	2.2.3	Scanning	Electron Microscopy (SEM)	27
	2.2.4	Transpor	t number	29
		2.2.4.1	EMF Method	30
		2.2.4.2	DC Polarization Method	30
	2.2.5	Energy D	ispersive Spectroscopy (EDS)	31
	2.2.6	Impedan	ce Spectroscopy	32
	2.2.7	Dielectri	c Permittivity	41
	2.2.8	Modulus	Formalism	44
2.3	Jonsch	er's Power L	aw	46
	Refere	ences		49
Chapter 3	Experimental Details			51-66
3.1	Introduction			53
3.2	Sample preparation method used in the present study			53
3.3	X-ray Diffraction (XRD) studies			
3.4	Density Measurements			
3.5	Scanning Electron Microscopy (SEM)			
3.6.	Transference Number Measurement (TN)			
3.7	Energy	y Dispersive	Spectroscopy	62
3.8	Impedance spectroscopy			63
	Refere	ences		66
Chapter 4	Characterization Results			67-98
4.1	X-ray Diffraction (XRD)			69
	4.1.1	Introductio	n	69
	4.1.2	X-ray Diffra	action of LiTi <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> (LTP) system	69
	4.1.3	X-ray Diffra	action for LATP sample	71

	4.1.4	X-ray Diffraction for LAYTP series	73	
	4.1.5	X-ray Diffraction for Heat Treated LAYTP series	75	
	4.1.6	X-ray Diffraction Studies of LAGTP Series	78	
	4.1.7	X-ray Diffraction Studies of LASTP series	80	
4.2	Densit	Density measurements		
	4.2.1	Density measurement of LiTi <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub> (LTP) and Li <sub>1.3</sub> Al <sub>0.3</sub> Ti $_{1.7}$ (PO <sub>4</sub> ) $_3$ (LATP) system	82	
	4.2.2	Density measurement of Li <sub>1.3</sub> Al <sub>0.3-x</sub> $Y_x$ Ti <sub>1.7</sub> (PO <sub>4</sub> ) <sub>3</sub> (LAYTP) system (where $x = 0.01, 0.03, 0.05, 0.07, 0.10$ and 0.015)	83	
	4.2.3	Density measurement of Heat Treated $\text{Li}_{1.3}\text{Al}_{0.3-x}\text{Y}_x\text{Ti}_{1.7}(\text{PO}_4)_3$ (LAYTP) system (where $x = 0.01$ and $0.015$ )	83	
	4.2.4	Density measurement of Li $_{1.3}$ Al $_{0.3-x}$ Ga $_x$ Ti $_{1.7}$ (PO $_4$ ) $_3$ (LAGTP) system. ( $x = 0.01, 0.03, 0.05, 0.07$ )	85	
	4.2.5	Density measurements of Li $_{1.3}$ Al $_{0.3-x}$ Sc $_x$ Ti $_{1.7}$ (PO <sub>4</sub> ) $_3$ (LASTP) system ( $x = 0.01, 0.03, 0.05, 0.07$ )	86	
4.3	Scanni	ing Electron Microscopy (SEM) Studies	86	
	4.3.1	SEM of LAYTP series	87	
	4.3.2	SEM of LAGTP series	88	
	4.3.3	SEM of LASTP series	89	
4.4	Transı	port Number Measurements	90	
4.5	Electro	ectron Dispersive Spectroscopy measurements		
	4.5.1	EDS of LAYTP series	91	
	4.5.2	EDS of LAGTP series	93	
	4.5.3	EDS of LASTP series	94	
	Refere	References		
Chapter 5	Condu	ctivity and dielectric relaxation behavior		
5.1	Introd	uction	101	
5.2	Condu	ctivity Studies	101	
	5.2.1	Reference LTP and LATP systems	101	
	5.2.2	LAYTP system	106	
	5.2.3	Heat Treated LAYTP system	113	
	5.2.4	LAGTP System	119	
	5.2.5	LASTP system	124	
5.3	Dielectric studies			
	5.3.1	Reference LTP and LATP systems	133	
	5.3.2	LAYTP system	136	
	5.3.3	Heat Treated LAYTP system	142	
	5.3.4	LAGTP system	146	

	5.3.5	Li <sub>1.3</sub> Al <sub>0.3-x</sub> Sc <sub>x</sub> Ti <sub>1.7</sub> (PO <sub>4</sub> ) <sub>3</sub> (LASTP) system	150
5.4	Modulus Analysis		
	5.4.1	Reference LTP and LATP systems	156
	5.4.2	LAYTP system	159
	5.4.3	Heat Treated LAYTP system	162
	5.4.4	LAGTP system	164
	5.4.5	LASTP system	166
	References		168
Chapter 6	Conclusions		
	List of Publications		