

# List of Figures

Chapter 1	Page
<b>Fig. 1.1</b> Schematic diagram showing the different forms of solid polymer electrolytes (SPEs).	4
<b>Fig. 1.2</b> Different types of composite solid polymer electrolytes (CSPEs) explored by various groups.	7
<b>Fig. 1.3</b> NASICON-type (a) rhombohedral (R3c) structure and (b) monoclinic (C2/c) structure (the yellow tetrahedra and the grey octahedra correspond to $\text{SiO}_4/\text{PO}_4$ and $\text{ZrO}_6$ units, respectively); Na ion conduction pathway in NASICON-type (c) rhombohedral and (d) monoclinic structure.	13
<b>Fig. 1.4</b> Ion chain coupling relaxation in polymer-salt system.	18
<b>Fig. 1.5</b> Schematic illustration of $\text{Na}^+$ ion transport in composites polymer electrolytes.	20
<b>Fig. 1.6</b> Schematic showing possible $\text{Li}^+$ transport pathways in the CPE.	21
<b>Fig. 1.7</b> Classification of different supercapacitors (SCs).	22
<b>Fig. 1.8</b> EDL models, (a) Helmholtz model, (b) Gouy–Chapman model, and (c) Stern model.	23
<b>Chapter 2</b>	
<b>Fig. 2.1</b> Schematic diagram for the synthesis of hybrid polymer-NASICON electrolyte adopted for $\text{Li}^+$ and $\text{Na}^+$ ion-based systems.	47
<b>Fig. 2.2</b> Schematic diagram of one-pot synthesis route.	48
<b>Fig. 2.3</b> (a) Schematic diagram of EDLC fabrication and (b) coin cell assembly.	51
<b>Fig. 2.4</b> (a) Geometrical representation of Bragg's law. (b) Block diagram of XRD setup.	52
<b>Fig. 2.5</b> (a) Block diagram of DSC set up and (b) DSC scan of a typical CSPE.	53

<b>Fig. 2.6</b> Block diagram of FESEM instrument set up.	54
<b>Fig. 2.7</b> (a) Electron excitation process scheme and (b) XAS spectra including both X-ray Absorption Near Edge Structure (XANES) and Extended X-ray Absorption Fine Structure (EXAFS).	56
<b>Fig. 2.8</b> Electron excitation process.	57
<b>Fig. 2.9.</b> Schematic diagram of (a) sample holder, and (b) IS measurement setup.	61
<b>Fig. 2.10</b> Typical $\sigma'$ - $\omega$ plot for ionic conducting SPEs. Range of spectrum lies from mHz to MHz.	62
<b>Fig. 2.11</b> (a) A typical graph of the transient ionic current behaviour with polarization time. (b) Schematic Nyquist plot for cell with before and after polarization along with polarization current with time.	65
<b>Fig. 2.12</b> (a) Block diagram of CV setup. (b) Block diagram of the two probe measurement of electrochemical performance	66
<b>Fig. 2.13</b> (a) A typical LSV curve showing ESW. (b) Typical CV curve for redox reaction.	67
<b>Fig. 2.14</b> A typical charge-discharge curve for SPEs.	68

### Chapter 3

<b>Fig. 3.1</b> X-ray diffraction patterns for samples 0-80 LTP. Index as per.	74
<b>Fig. 3.2</b> (a) DSC thermograms (heat flow is normalized w.r.t. PEO amount in each composition) for the solid polymer composites with various LTP content. Approximate O/Li ratio is also given for each sample. (b) PEO Crystallinity as a function of LTP content. $\Delta H_{0m}$ is the actual melting enthalpy as obtained from the DSC experiment for pristine PEO. Pristine PEO crystallinity is considered 100% and used as a reference to define other crystallinities.	75
<b>Fig. 3.3</b> Electrical conductivity (1kHz) as a function of LTP content. (For $x \leq 0.4$ polymer films; $x > 0.4$ pellets). Inset shows images of (i) 40 LTP film and (ii) 90LTP pellet of diameter 8 mm.	76
<b>Fig. 3.4</b> Electrical conductivity-temperature cycles obtained at 1kHz for polymer composite samples with various LTP content. (For $x \leq 0.4$ polymer	77

films;  $x > 0.4$  pellets). 80 LTP-I and II refer to first and second heating cycles of 80LTP sample

**Fig. 3.5** Electrical conductivity versus frequency for samples with (a) 40 LTP, (b) 70 LTP, and (c) 90 LTP content. Inset of b and c shows the apparent dc to dispersion in high frequency region.  $\sigma_{LTP}$  is calculated from the onset of this dispersion 79

**Fig. 3.6** Temperature dependency of electrical conductivity for high LTP content samples. Polymer-grain boundary conductivity ( $\sigma_{PGB}$ ) and (b) bulk conductivity ( $\sigma_{LTP}$ ). 80

**Fig. 3.7** Arrhenius plot for fixed O/Li ratio of 13:1 for 80LTP and its analogue 80L ATP hybrid. 80

**Fig. 3.8** XRD patterns for 0 L ATP, 20 L ATP, 40 L ATP, and 70 L ATP hybrid CPEs. Inset shows DSC thermograms of hybrid CPEs viz. 0 L ATP, 20 L ATP, 40 L ATP, and 70 L ATP. 82

**Fig. 3.9** FESEM images of the composites (a) 0 L ATP (b) 40 L ATP and (c) 70 L ATP. (d) EDS mapping image for 70 L ATP sample. (e) Elemental distribution of C, S, P, Ti and F for 70 L ATP sample. 83

**Fig. 3.10** Nyquist plot for Ag|0L ATP|Ag cell configuration at different temperatures. Inset shows (i) the same for 40 L ATP at different temperatures and (ii) corresponding equivalent circuits for 40 and 70 L ATP 84

**Fig. 3.11** (a) For 70 L ATP, temperature dependence of ionic conductivity of components, viz. polymer-grain boundary ( $\sigma_{PGB}$ ) and L ATP grains ( $\sigma_{L ATP}$ ). (b) Total ionic conductivity versus temperature for 0-70 L ATP samples 85

**Fig. 3.12** Scaling behaviour of electrical conductivity at room temperature for CPEs  $5LiCF_3SO_3-95[PEO_{1-x}L ATP_x]$  where  $0 \leq x \leq 0.7$ . Inset: 70 L ATP composites with temperature 86

**Fig. 3.13** (a) Nyquist plots for Li|70L ATP|Li cell configuration before and after polarization. Inset shows (i) corresponding equivalent circuit and (ii) polarization (ionic) current profile with time. (b) Transient ionic current during reversing of potential with respect to time for 0 L ATP, 40 L ATP, 50 L ATP and 70 L ATP in a cell configuration of Ag/sample/Ag. Inset shows extended graph for 70 L ATP sample. 87

## Chapter 4

- Fig. 4.1** XRD patterns for Pristine PEO film, composite SPEs (0 NTP, 40 NTP and 70 NTP) and milled NTP powder sample. 92
- Fig. 4.2** EDS mapping over FE-SEM image for (a) 40 NTP and (b) 70 NTP hybrid composite. Total elemental distribution of Na, I, and Ti elements by EDS for (c) 40 NTP and (b) 70 NTP Composite 93
- Fig. 4.3** (a) Frequency dependence of conductivity at various temperatures for 40 NTP hybrid composite. Inset: Nyquist plot at 303 K and photograph of film. (b) Frequency dependence of conductivity at various temperatures for 70 NTP hybrid composite. Inset: Nyquist plot at 303 K and photograph of pellet 94
- Fig. 4.4** Temperature dependent dc conductivity for hybrid composites of composition 10NaI- 90(PEO<sub>1-x</sub>NTP<sub>x</sub>),  $0 \leq x \leq 0.7$ . Plot with 70 NTP I and 70 NTP II corresponds to first and second heating cycles for 70 NTP composite. Inset: DSC thermogram for 0, 40 and 70 NTP samples. The dash line is a guide to eye to show deviation from Arrhenius behaviour near melting of PEO. 95
- Fig 4.5** (a) Conductivity scaling behaviour for 70 NTP composite with temperature variation. Inset: The same on extended scale. (b) Conductivity scaling behaviour at room temperature with varied composition of NTP: 10NaI-90(PEO<sub>1-x</sub>NTP<sub>x</sub>),  $0 \leq x \leq 0.7$ . Inset: The same on an extended scale. 96
- Fig. 4.6** Frequency dependent conductivity at different temperatures for (a) 0 NTP and (b) 40 NTP hybrid SPEs. The arrow indicates two well separated dc to dispersion regions, more apparently visible at lower temperatures 97
- Fig. 4.7** Temperature dependent dc conductivity for sample with 0 NTP and 40 NTP. 98
- Fig. 4.8** Frequency dependence of electric modulus ( $M''$ ) for 0 NTP and 40 NTP composites with temperature (for  $T > T_g$ ). 99
- Fig 4.9** Transient ionic current versus time for 50 NTP, 60 NTP and 70 NTP with polarization voltage of 0.5 V. Inset: Time of flight ( $\tau$ ) measurement from 70 NTP on an extended scale. 100
- Fig 4.10** Temperature dependence of dc conductivity for 10NaI-90(60PEO40 M), where M corresponds to dispersoids NTP, Al<sub>2</sub>O<sub>3</sub> and NZSP (Na<sub>3</sub>Zr<sub>2</sub>Si<sub>2</sub>PO<sub>12</sub>) of almost same crystallite size of ~ 30 nm 101

**Fig. 4.11** (a) XRD patterns for composites 10NaI-90[PEO<sub>1-x</sub>NZSP<sub>x</sub>], where  $x = 0, 0.4, 0.7$  along with pristine PEO and NZSP, (b) FESEM images for 40 and 70 NZSP composite at 1  $\mu\text{m}$  and 500 nm scale

**Fig. 4.12** (a) Temperature dependence (1 kHz) of ionic conductivity for composites 10NaI-90[PEO<sub>1-x</sub>NZSP<sub>x</sub>], where  $0 \leq x \leq 0.7$  and, (b) Nyquist plots (normalized with thickness for comparison and area of cross section is kept same for all samples) for 0, 40, and 70 NZSP at different temperatures for cell configuration of SS|SPE|SS. The solid line in the Nyquist plot shows the best fit using the equivalent circuit in the inset.

**Fig. 4.13** (a) Nyquist plots for composites with  $x = 0.13$  and 0.03 (inset). Dotted lines represent corresponding fitted models. (b) Temperature dependence of total conductivity obtained from Nyquist plots for all composites. Inset:  $\sigma$ -T cycles (1 kHz) at a heating rate of  $1^\circ\text{C min}^{-1}$  to observe effect of polymer melting on electrical transport.

**Fig. 4.14** XRD patterns for composites with  $x = 0.03$ -0.13.

**Fig. 4.15** (a) and (b) FESEM images for composite with  $x = 0.03$  and 0.13, respectively.

## Chapter 5

**Fig. 5.1** (a) Normalized XANES spectra for Oxygen (O) K-edge of pristine PEO film. The marked arrow represents K-edge energy values for oxygen. (b) Normalized XANES spectra for carbon (C) K-edge of pristine PEO film. The marked arrow represents K-edge energies for carbon. Instrument resolution: 0.1 eV.

**Fig. 5.2** (a) Normalized XANES spectra with NTP variation for oxygen. The peak assignment corresponding to I, II and III are given in Table 1. (b) Normalized XANES spectra with NTP variation for carbon. The peak assignment corresponding to IV, V, and VI are given in Table 1. Instrument resolution: 0.1 eV.

**Fig. 5.3**  $1s \rightarrow \sigma^*$  transition energy for O K-edge XANES spectra (corresponding to peak II in Fig 5.2a) versus NTP content. Inset:  $1s \rightarrow \sigma^*$  transition energy for carbon K-edge spectra (from peak-IV, V and VI in Fig. 5.2 b). Instrument resolution: 0.1 eV.

**Fig. 5.4** Normalized XANES spectra processed using ATHENA software. Inset: O-K edge energy ( $E_0$ ) variation with salt addition. Instrument resolution: 0.1 eV. 117

**Fig. 5.5** (a) Normalized XANES spectra for O K-edge with varied LATP content. Inset shows peak derivative of XANES spectra for PEO, 40 LATP and 70 LATP sample. (b) O K-edge energy ( $E_0$ ) obtained from peak derivative of XANES spectra with LATP content. Instrument resolution: 0.1 eV. 118

**Fig. 5.6** Normalized XANES spectra for Ti L-edge with varied LATP content. Inset shows Ti Ledge energy values correspond to  $t_{2g}$  and, e.g., transition for L2 and L3 edge. 119

**Fig. 5.7** Core level (O 1s) XPS spectra with deconvoluted peaks for composite (a)  $x = 0$ , (b)  $x = 0.1$ , (c)  $x = 0.3$ , (d)  $x = 0.4$ , (e)  $x = 0.5$ , (f)  $x = 0.6$ , (g)  $x = 0.7$  and (h) Pristine LATP. The complete core level spectrum is represented by dotted red colour line. Further the convoluted spectra is represent by brown colour line. Instrument resolution: 0.01 eV. 124

**Fig. 5.8** Binding energy (O 1s) corresponding to ether oxygen of PEO with LATP variation in  $5\text{LiCF}_3\text{SO}_3\text{-}95[\text{PEO}_{1-x}\text{LATP}_x]$  composites. Dotted lines denote deviation from monotonic rise of binding energy. Inset: Binding energy of LATP oxygens (O 1s (3) and O 1s (4)) with its variation in the matrix. Instrument resolution: 0.01 eV. 125

**Fig. 5.9** Core level (O 1s) XPS spectra with deconvoluted peaks for 63NZSP- $[\text{PEO}_{1-y}\text{NaI}_y]$  composite (a)  $y = 0.03$ , (b)  $y = 0.07$ , (c)  $y = 0.11$  (d)  $y = 0.13$  and (e) pristine NZSP. Similar to Fig. 5.7, the complete core level spectrum is represented by dotted red colour line and convoluted spectra is represent by brown colour line. Instrument resolution: 0.01 eV. 127

**Fig. 5.10** Binding energy (O 1s) corresponding to ether oxygen of PEO with salt concentration variation in  $63\text{NZSP-}[\text{PEO}_{1-x}\text{NaI}_x]$  composites. Inset: Binding energy for NZSP oxygens (O 1s (2) and O 1s (3)) with its variation in the matrix. Instrument resolution: 0.01 eV 128

**Fig. 5.11** Temperature dependent ionic conductivity for samples with NASICON and without NASICON content in respective polymer matrix below room temperature (220–300 K) for (a) LATP-PEO- $\text{LiCF}_3\text{SO}_3$  system and (b) NZSP-PEO-NaI system. 129

**Fig. 5.12** Generalized ion transport mechanism in polymer-NASICON hybrid composites 130

## Chapter 6

**Fig. 6.1** (a) Nitrogen adsorption-desorption isotherm curve of the activated carbon (inset: linear fitting with BET equation), (b) Micropore distribution plot of the activated carbon and, (c) FESEM images for the deposited AC electrode on copper and graphite current collectors. 136

**Fig. 6.2** CV of EDLC cells ( $10\text{mV}\cdot\text{s}^{-1}$ ) with configuration of  $\text{AC}|\text{10NaI}-(\text{PEO}_{1-x}\text{NZSP}_x)|\text{AC}$  where  $x = 0, 0.4$  and  $0.7$  using (a) copper and (b) graphite as current collectors. Inset: corresponding Nyquist plots. (c) Nyquist plot for the device with 40 and 70 NZSP with Graphite as a current collector. (d) Nyquist plot for the device with 40 NZSP electrolyte for graphite and copper collector 138

**Fig. 6.3** CV scans at  $10$  and  $50\text{mV}\cdot\text{s}^{-1}$  for EDLCs with 40 NZSP composite as electrolyte with (a) copper and (b) graphite current collectors; specific charge-discharge capacitance at different current densities for EDLCs with (c) copper and (d) graphite current collectors. 140

**Fig. 6.4** Galvanostatic charge-discharge curves upto 400 cycles for EDLCs with 40 NZSP composite as electrolyte with (a) copper ( $2\text{mA}$ ) and (b) graphite current collector ( $2\text{mA}$ ). 143

**Fig. 6.5.** Specific charge-discharge capacitance of the EDLCs with 40 NZSP composite as electrolyte and current collectors viz. (a) copper and (b) graphite. Inset: Specific discharged capacitance with cycle number. 143

**Fig. 6.6** (a) XRD patterns of pristine MWCNT,  $\text{MnO}_2$ , and MWCNT- $\text{MnO}_2$ . (b) Raman spectra of pristine MWCNT and MWCNT- $\text{MnO}_2$  composite. (c) FESEM images of pristine MWCNT and MWCNT- $\text{MnO}_2$  composite. 145

**Fig. 6.7** Nyquist plot for cell with configuration of  $\text{MWCNT}:\text{MnO}_2 (1:1)|\text{10NaI}-90[\text{PEO}_{0.6}\text{NZSP}_{0.4}]|\text{MWCNT}:\text{MnO}_2 (1:1)$ . Inset shows for the cell with configuration of  $\text{MnO}_2|\text{10NaI}-90[\text{PEO}_{0.6}\text{NZSP}_{0.4}]|\text{MnO}_2$ . 146

**Fig. 6.8** (a) CV scan at  $1\text{mV}\cdot\text{s}^{-1}$ , (b) CV scan at different sweep rate and (c) galvanostatic charge discharge curve for cell with configuration of  $\text{MWCNT}:\text{MnO}_2 (1:1)|\text{10NaI}-90[\text{PEO}_{0.6}\text{NZSP}_{0.4}]|\text{MWCNT}:\text{MnO}_2 (1:1)$ . 147

## Chapter 7

- Fig. 7.1** Temperature dependence of dc conductivity for 10NaI-90(60PEO40 M), where M corresponds to dispersoids NTP, Al<sub>2</sub>O<sub>3</sub>, and NZSP (Na<sub>3</sub>Zr<sub>2</sub>Si<sub>2</sub>PO<sub>12</sub>) of almost same crystallite size of ~ 30 nm 155
- Fig. 7.2** Effect of grain conductivity in CSPEs at 40°C for same NASICON content (36 wt %). 156
- Fig. 7.3** Highest conductivity achieved for CSPEs compared with polymer salt complex at 40°C. 157
- Fig. 7.4** Ionic conductivity of the CSPEs in pellet form at 40°C with days 158



# List of Tables

## Chapter 1

<b>Table 1.1</b> Different types of polymer hosts along with their physicochemical properties	3
<b>Table 1.2</b> Various polymer-Salt complexes as reported	5
<b>Table 1.3</b> Electrical properties of some important Na <sup>+</sup> ion conducting polymer-alkali salts complexes electrolytes. ESW, OCV, and SSC stand for electrochemical stability window, open circuit voltage, and short circuit current, respectively.	6
<b>Table 1.4</b> Li <sup>+</sup> ion conducting composite polymer electrolytes containing inactive fillers	9
<b>Table 1.5</b> Na <sup>+</sup> ion conducting composite polymer electrolyte with inactive fillers.	10
<b>Table 1.6</b> Li <sup>+</sup> /Na <sup>+</sup> ion conducting fast ionic conductors	12
<b>Table 1.7</b> Composite polymer electrolyte with Li <sup>+</sup> ion conducting active fillers.	15
<b>Table 1.8</b> Some of the recent Na <sup>+</sup> ion-conducting composite solid polymer electrolytes with active fillers.	17
<b>Table 1.9</b> BET specific surface areas ( $S_{bet}$ ) for different carbon precursors.	24

## Chapter 2

<b>Table 2.1</b> The interrelationship of the three formalisms of impedance spectroscopy	60
<b>Table 2.2</b> Various possible impedance models that can be applied to various samples as per their electrical properties	63

## Chapter 3

<b>Table 3.1</b> Calculated O/Li ratio, Li <sup>+</sup> ion transport number and ionic mobility for 0-70 LATP composites	88
--	----

## Chapter 4

<b>Table 4.1</b> Ionic mobility using TIC technique for various compositions	100
--	-----

## Chapter 5

<b>Table 5.1</b> Peak positions assigned to various excitations in XANES spectra	114
--	-----

<b>Table 5.2</b> Peak position and their relative peak area ratio correspond to deconvoluted O 1s spectra for composites 5LiCF <sub>3</sub> SO <sub>3</sub> -95[PEO <sub>1-x</sub> LATP <sub>x</sub> ] and pristine LATP. Here * refers peak that are difficult to identify due to low content and overlapping. The residual standard deviation for all the fitting was found to be ~1 eV.	122
--	-----

<b>Table 5.3.</b> Peak position and their relative peak area ratio correspond to deconvoluted O 1s spectra for composites 63NZSP-[PEO <sub>1-y</sub> NaI <sub>y</sub> ] and pristine NZSP. The residual standard deviation for all the fitting was found to be ~1eV.	123
--	-----

## Chapter 6

<b>Table 6.1</b> Calculated values of the Equivalent series resistance (ESR <sub>e</sub> ), specific capacitance (Cs), specific energy (Es), and specific power (Ps) (From Fig. 3c and d) at different discharge current densities. The error bars are noted as ± 5 F-g <sup>-1</sup> , ± 5 Wh Kg <sup>-1</sup> , ± 5 kW Kg <sup>-1</sup> , respectively for Cs, Es, and Ps.	142
--	-----

<b>Table 6.2.</b> Calculated values of the Equivalent series resistance (ESR <sub>e</sub> ), specific capacitance (Cs), specific energy (Es), and specific power (Ps) (From Fig. 8) at different discharge current densities. The error bars are noted as ± 2 F-g <sup>-1</sup> , ± 2 Wh Kg <sup>-1</sup> ± 2 kW Kg <sup>-1</sup> , respectively for Cs, Es, and Ps.	148
--	-----

<b>Table 6.3.</b> Calculated values of the specific capacitance (Cs), specific energy (Es) and specific power (Ps) for cell with 40 NZSP as electrolyte at 1A-g <sup>-1</sup> discharge current. The error bars are noted as ± 5 F-g <sup>-1</sup> , ± 5 WhKg <sup>-1</sup> , ± 5 kW Kg <sup>-1</sup> , respectively for Cs, Es, and Ps	148
---	-----

## Abbreviations

<b>LIB</b> : Li-ion battery	<b>SPE</b> : Solid Polymer Electrolyte
<b>LICs</b> : Lithium-ion capacitors	<b>PEO</b> : Polyethylene Oxide
<b>EVs</b> : Electric vehicles	<b>EC</b> : Ethylene Carbonate
<b>SEs</b> : Solid electrolytes	<b>PC</b> : Propylene Carbonate
<b>FICs</b> : Fast ionic solids	<b>PEG</b> : Polyethylene Glycol
<b>NASICONS</b> : Sodium Superionic Conductors	<b>SHE</b> : Standard Hydrogen Electrode
<b>GBI</b> : Grain Boundary Impedance	<b>ESW</b> : Electrochemical Stability Window
<b>ASSB</b> : All-Solid-State Batteries	<b>OCV</b> : Open Circuit Voltage
<b>SSC</b> : Short Circuit Current	<b>PMMA</b> : Poly(methyl methacrylate)
<b>CSPEs</b> : Composite Solid Polymer Electrolytes	<b>EC</b> : Ethylene Carbonate
<b>T<sub>g</sub></b> : Transition Temperature	<b>PVA</b> : Poly(Vinyl Alcohol)
<b>CPE</b> : Composites Polymer Electrolytes	<b>PVdF</b> : Poly(Vinylidene Fluoride)
<b>VTF</b> : Vogel-Tamman-Fulcher	<b>PVACC</b> : Poly(Vinyl Alcohol) Ceramic Composite
<b>SC</b> : Supercapacitor	<b>CP</b> : Composite Polymer
<b>EDLC</b> : Electrochemical Double-Layer Capacitors	<b>XAS</b> : Soft X-ray Absorption Spectroscopy
<b>CNT</b> : Carbon Nanotubes	<b>XANES</b> : X-ray Absorption Near-Edge Spectroscopy
<b>PC</b> : Propylene Carbonate	<b>XPS</b> : X-ray Photoelectron Spectroscopy
<b>DEC</b> : Diethyl Carbonate	<b>ASSCs</b> : All-Solid-State Supercapacitors
<b>DME</b> : Dimethyl Carbonate	<b>ACs</b> : Activated carbons
<b>RPM</b> : Round Per Minute	<b>FESEM</b> : Field emission scanning electron microscopy
<b>MWCNT</b> : Multiwalled Carbon Nanotubes	<b>EDX or EDS</b> : Energy Dispersive X-ray Spectroscopy
<b>NMP</b> : 1-Methyl-2-pyrrolidinone	<b>SXAS</b> : Soft X-ray absorption spectroscopy

<b>XRD</b> : X-ray diffraction	<b>XANES</b> : X-ray absorption near edge structure
<b>DSC</b> : Differential Scanning Calorimetry	<b>EXAFS</b> : extended X-ray absorption fine structure
<b>T<sub>g</sub></b> : glass transition	<b>XPS</b> : X-ray photoelectron spectroscopy
<b>T<sub>m</sub></b> : melting event	<b>BE</b> : binding energy
<b>KE</b> : kinetic energy	<b>FIC</b> : Fast Ionic Conductor
<b>BET</b> : (Brunauer, Emmett, and Teller) technique	<b>PVDF-HFP</b> : poly(vinylidene fluoride-co-hexafluoropropene)
<b>STP</b> : Standard Temperature and Pressure	<b>PAN</b> : Polyacronitrile
<b>IS</b> : Impedance spectroscopy	<b>GPE</b> : Gel Polymer Electrolyte
<b>JPL</b> : Jonscher power law	<b>EDS</b> : Elemental Distribution Spectroscopy
<b>ω<sub>p</sub></b> : Hopping Rate	<b>NTP</b> : NaTi <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub>
<b>CPE</b> : Constant Phase Element	<b>TEABF<sub>4</sub></b> : Tetraethylammonium Tetrafluoroborate
<b>σ<sub>dc</sub></b> : DC Conductivity	<b>LiAsF<sub>6</sub></b>
<b>LSV</b> : Linear Sweep Voltammetry	<b>NZSP</b> : Na <sub>3</sub> Zr <sub>2</sub> Si <sub>2</sub> PO <sub>12</sub>
<b>CV</b> : Cyclic Voltammetry	<b>XPS</b>
<b>GCD</b> : Galvanostatic Charge-Discharge	<b>LLZO</b> : Li <sub>7</sub> La <sub>3</sub> Zr <sub>2</sub> O <sub>12</sub>
<b>DSC</b> : Differential scanning calorimetry	<b>LLTO</b> : Li <sub>0.33</sub> La <sub>0.557</sub> TiO <sub>3</sub>
<b>σ<sub>PGB</sub></b> : Grain Boundary Conductivity	<b>LATP</b> : Li <sub>1+x</sub> Al <sub>x</sub> Ti <sub>2-x</sub> (PO <sub>4</sub> ) <sub>3</sub>
<b>PID</b> -controlled furnace	<b>LTP</b> : LiTi <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub>
<b>PMA</b> : Polymethyl Acrylate	<b>LATP</b> : Li <sub>1.3</sub> Ti <sub>0.7</sub> Al <sub>0.3</sub> (PO <sub>4</sub> ) <sub>3</sub>
:Linear Sweep Voltammetry	<b>NTP</b> : NaTi <sub>2</sub> (PO <sub>4</sub> ) <sub>3</sub>
<b>EIS</b> : Electrochemical Impedance Spectroscopy	<b>NZSP</b> : Na <sub>3</sub> Zr <sub>2</sub> Si <sub>2</sub> PO <sub>12</sub>