Chapter 6

Summary and future work
The work in this thesis deals with polymer electrolyte composites. The field of polymer electrolyte composites is very huge and in the present work, a small step has been taken in the direction to understand the conductivity modification in these composites. Three types of dispersoids have been chosen to be dispersed in the PEO:NH$_4$I (90:10wt.%) polymer electrolyte. Graphene (semiconducting), SiO$_2$ (insulating) and transition metal oxides, Fe$_3$O$_4$, NiO, Mn$_3$O$_4$, Co$_3$O$_4$, (magnetic) have been chosen as dispersoids. The characterization of the polymer electrolyte composites has been done for understanding their structural, morphological, thermal and electrical behaviour. The chapter-wise overview is as follows:

**Chapter 1** contains the literature review and brief introduction on solid state ionics, polymers, polymer electrolytes and polymer electrolyte composites. The chapter gives information about different types of ionic conductors in brief. To explain the ion conduction in composites, a short overview of different models has been given. The chapter also gives a brief write-up on some of the applications of polymer electrolyte materials like, solid state batteries, fuel cells, super capacitors and electrochromic display devices. In the last section of this chapter, the objective of the work presented in this thesis is briefly described.

**Chapter 2** gives the experimental techniques used in the present work and includes the method of obtaining the polymer electrolytes and their composites by solution cast technique. Various experimental techniques can be used to characterize the different properties of polymer composites. For the evaluation of the bulk electrical conductivity of the composites, a description of the impedance spectroscopic techniques has been given. Wagner's polarization method has been described for transport number measurements. To study the thermal properties of the polymer electrolyte composites, differential scanning calorimetry (DSC) and thermo-gravimetric analysis (TGA) have
been described. X-ray diffraction (XRD), Raman spectroscopy, positron annihilation lifetime spectroscopy (PALS) and scanning electron microscopy (SEM) have also been presented which have been used to study the structural and morphological properties of the polymer electrolyte composites. A brief description about transmission electron microscopy (TEM), Fourier transform infra-red spectroscopy technique (FTIR) has also been given. For the magnetic measurements, vibrating sample magnetometer (VSM) technique used, has been given in this chapter. A description of the vector network analyzer (VNA) used for measuring shielding parameters of the TMO dispersed polymer electrolyte composites, has also been given.

Chapter 3 deals with mixed conductors. Polymer electrolyte composites (PEO: NH₄I) with dispersed graphene have been prepared. The composites have been prepared by solution cast technique. Graphene dispersal introduces partial electronic conductivity in the ion conducting polymer electrolyte. Electrical and transport number study has been done for the composites. The plot of conductivity vs. composition of graphene in the composites exhibits two peaks which have been explained on the basis of changes in crystallinity (XRD & DSC) of the host polymer and establishment of percolation paths (TEM). Conformational and structural changes have been investigated by Raman spectroscopy and positron annihilation lifetime spectroscopy (PALS).

Chapter 4 deals with the effect of the particle size of the dispersoid on the percolation threshold and the extent of maximum conductivity enhancement for the composites. Silica particles of different diameters (0.007, 0.014 and 44 μm) have been dispersed in the polymer electrolyte, (PEO:NH₄I), to form composites and their electrical and thermal behaviour has been studied. The role of degree of crystallinity/amorphicity of the composites in modifying the conductivity of the composites has also been discussed and a phenomenological explanation has been suggested. The conductivity study shows that there are two peaks in the conductivity versus composition of SiO₂. A shift in the percolation threshold for conductivity as a function of the particle size of the dispersoid (SiO₂) is seen. The shift has been explained using the crystallite size, strain and melting temperatures of the composites.
**Chapter 5** deals with studies on polymer electrolytes nanocomposites of PEO:NH$_4$I dispersed with transition metal oxides (TMOs), Fe$_3$O$_4$, NiO, Mn$_3$O$_4$ & Co$_3$O$_4$ nanoparticles. The aim of this study is to demonstrate the influence of varying amounts of TMO nanoparticles on the electrical and magnetic properties of these magnetic nanocomposites. The amount and saturation magnetization of the magnetic filler is directly responsible for magnetic behaviour of obtained nanocomposites. The combination of polymer electrolyte and magnetic particles can form a composite with electromagnetic properties. Transition metal oxide nanoparticles have been synthesized by known chemical methods. Superparamagnetic behaviour has been obtained in both, Fe$_3$O$_4$ and its composites. Iron oxide dispersed composites show the best results possessing saturation magnetization (Ms) value of ~ 3 emu/g with conductivity of 1.6E-5 S/cm which have been determined by VSM and impedance spectroscopy, respectively. Crystallite size and morphological study of the TMO nanoparticles have been done to relate them to the conductivity variation of the composites. The chapter also contains the magnetic field dependence of conductance of iron oxide dispersed composites. Shielding effectiveness due to absorption and reflection of the composites has been calculated. The Fe$_3$O$_4$ dispersed composites also show a potential to be used as medium magnetic field sensor.

For future work, to study the microwave absorption and shielding properties, it is proposed to synthesize polymer electrolyte composites with appropriately high conductivity with dispersed TMOs. Also, it is proposed to prepare polymer electrolyte composites with magnetic particles in the presence of varying magnetic field. Synthesis of polymer composites with conducting polymers having dispersed magnetic particles is also proposed.