7 Conclusion and Future Scope

7.1 Summary of the thesis research work

The thesis work mainly deals with the investigation of structural and electrical properties of undoped and doped $SrCeO_3$. It has been concluded that a few acceptors (Na^+, Gd^{3+}, and La^{3+}) doped $SrCeO_3$ systems have been synthesized for the first time by solid-state ceramic method and auto combustion method. Samples $SrCeO_3$(SC), $SrCe_{0.98}Na_{0.02}O_3$(SCN2), $SrCe_{0.96}Na_{0.04}O_3$(SCN4), $SrCe_{0.94}Na_{0.06}O_3$(SCN6), $SrCe_{0.90}Na_{0.10}O_3$(SCN10), $SrCe_{0.98}Gd_{0.02}O_3$ (SCG2), $SrCe_{0.96}Gd_{0.04}O_3$ (SCG4), $SrCe_{0.94}Gd_{0.06}O_3$ (SCG6) and $SrCe_{0.90}Gd_{0.10}O_3$ (SCG10) were synthesized by solid-state reaction method. Whereas samples $SrCeO_3$ (SCL0), $SrCe_{0.98}La_{0.02}O_3$(SCL2), $SrCe_{0.96}La_{0.04}O_3$(SCL4), $SrCe_{0.94}Na_{0.06}O_3$(SCL6) and $SrCe_{0.90}La_{0.10}O_3$ (SCL10) were synthesized by auto combustion method. The synthesized samples have been characterized by using DTA-DSC, XRD, Raman, FTIR, UV-Vis, SEM and XPS techniques. For the electrical characterization, AC conductivity and DC conductivity of the samples have been measured in the temperature range 300-600°C and frequency range 20 Hz-2 MHz's The relaxation phenomenon of the synthesized samples has been studied using Complex plane impedance spectroscopy. This chapter presents a concise summary based on the results of the previous chapters and the discussions. The main outlines and summary of the present thesis are focused on the following points:

1. Thermogravimetric analysis (TGA) & Differential scanning calorimetry (DSC) studies combined with X-ray diffraction (XRD) technique confirmed that the single phase powder of these samples can be obtained by calcination ≥ 1000 °C.
2. Rietveld refinement of XRD data has confirmed that all the samples synthesized in this work have orthorhombic crystal and space group ($Pnma$).
3. Raman spectroscopy has confirmed the $SrCeO_3$ type structure and the presence of oxygen vacancies in the samples.

4. . Fourier transform infrared (FTIR) spectroscopy studies has indicated the presence of trace amount of $SrCO_3$ in the samples.
5. The UV-Vis spectroscopy studies of the samples suggested that band of $SrCeO_3$ is 3.10 eV. Increase/decrease in the value of band gap has been observed depending on the nature of the dopant.
6. Morphological studies of sintered ceramic pellets by Scanning electron microscopy (SEM) have shown that Na doped samples have lower sintering temperature than Gd and La-doped samples. Further, it was realized that for different dopants sintering temperature should be different. The average grain size of the samples lies 1 - 3.5 μm.
7. The X-ray photoelectron spectroscopy (XPS) studies of a few representative samples indicated that in the synthesized samples, Ce exists in both Ce^{3+} and Ce^{4+} states. Further, the XPS confirmed the presence of a large number of oxygen vacancies ($V_{\ddot{O}}$) at the surface of the samples.
8. In 2% Gd^{3+} doped and 4% La^{3+} doped $SrCeO_3$ lowest activation energy and highest conductivity (~10^{-3} S-cm^{-1}) is observed, found to be more suitable for proton conductor.

7.2 New Directions and Future Perspectives

The basic properties of proton conductor as electrolyte materials like microstructure, density, thermal and electrical compability for solid oxide fuel cells (SOFCs) depend on their synthesis route, dopants concentrations and microstructures. In this context, to achieve good conductivity and better performance of the materials, these parameters must be optimized. The microstructure is quite sensitive to the processing parameters such as sintering temperature, atmosphere used during sintering, processing routes and also the amount of extra phase infiltration. So a detailed study on the effect of these processing parameters on the structural, microstructural, thermal and electrical properties of the investigated compositions is required. An exercise of the optimization of the concentration of dopants is very much needed to enhance the oxygen ion conductivity of acceptor doped $SrCeO_3$ systems. Further, the following points may be considered also for future studies.

1. Some of the novel and exotic proton conducting electrolyte system should be developed which can have optimized ionic conductivity and may be considered in perspective of chemical and thermal stability and most importantly their operation at low or intermediate temperature range.
2. The conductivity behaviour of the sample at different partial pressure of oxygen should be studied to know the pressure range in which the conductivity is purely ionic.
3. The measurement of transference number is one of the important factors to predict the nature of the conductivity of electrolyte samples.
4. The measurement of Seebeck and Hall coefficients of the samples to understand electrical properties of the samples in more detailed.
5. The measurement of thermal expansion coefficient will be useful to study the compatibility of these electrolytes with the other component of cells.

6. The performance of the optimized electrolyte systems may be checked their compatible with anodes and cathodes.
7. Application oriented measurements to explore possibility of use of these materials in device fabrication.
8. A theoretical investigation of the ionic conductivity is important that should be carried out using DFT calculations because it can be used to explore how dopant types and dopant concentrations influence the ionic conduction and to understand the mechanisms of diffusion in doped electrolyte systems.